CHARACTERIZATION OF SPATIAL VARIABILITY OF SOIL PHYSICAL PROPERTIES AT UTP CAMPUS

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by

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CERTIFICATION OF APPROVAL

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Approved by,

(Dr. Rezaur Rahman Bhuiyan)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Azhiim.

MHD AZHIIM BIN RAZAK

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First and foremost, I would like to thank to God because by His willing, my Final Year Project (FYP) has finally completed.

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Abstract

This paper describes the experimental of the characterization of spatial variability of soil physical properties at UTP campus. The objective of the experiment are to characterize spatial structure of soil physical properties under tropical climate in terms of semivariogram parameters, to map the variation in soil physical properties in UTP campus, and to evaluate the effect of land use changes on the variability of soil physical properties. All of the planned project activities and tool required were explained in details further in this report. The study indicated geostatistical analysis in conjunction with conventional statistical analysis could reveal spatial variability nature of soil properties and causes behind the variability. Of significance importance to land management to land management practices is the finding that the variability of the soil properties are largely due to topographic features and land disturbances.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Spatial variability of soil physical properties are important analysis which to determine the optimum size of spatial for distributed parameter hydrological models, estimating point or spatially averaged values of soil properties that using kriging technique, in designing sampling networks and improving their efficiency .The Global Positioning System (GPS) is used for locating the sample position. Finding the variability of the soil properties is largely important to land management practices due to topographic features and land disturbances.

Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristics and precludes characterization of soil hydrological response. Recently, one of the major issues that has been increasing concern about how to estimate attribute of spatially varying of soil physical properties.

There are several form analysis that are important for characterization of spatial structure of soil engineering properties: (1) to determine the optimum size of spatial grids for distributed parameter hydrological models, (2) estimating point or spatially averaged values of soil properties using kriging methods, (3) in designing sampling networks and improving their efficiency.

There have 3 steps to be done for this experimental, which are the study area, soil sampling and laboratory analysis, and statistical and geostatistcal analysis.

1.1.1. The study area

The study was conducted in the University Technology Petronas(UTP) which located in Bandar Seri Iskandar that established on January 10,1997.The campus area is 400 ha (1000acres).

1.1.2 Soil sampling and the laboratory analysis

Global Positioning System (GPS) was used for locating the sample position with an error of ±1m.Fifty soil samples were collected at each location using a stainless steel auger. Then the soil samples were transferred to laboratory for analysis which to determine the soil physical properties; bulk density, moisture content, specific gravity, particle size distribution, and the organic content.

1.13 Statistical and Geostatistical Analysis

The result of the laboratory tests on soil engineering properties were subjected to two types of analysis: normal statistical and geostatistical analysis. Normal statistical analysis included determination of maximum, minimum, mean, standard deviation, and coefficient of variation of soil engineering properties.

While for the geostastical analysis included examining spatial variability nature of the soil engineering properties over the study area by determining the semivariogram parameters (the sill, nugget, range).

This proposed project will allow understanding and characterization of small scale spatial variability nature of physical properties at UTP campus area. This will also allow identifying the effects of land disturbances and catchments characteristics in UTP campus area.

1.2 Problem Statement

University Technology Petronas(UTP) is built on a 400 hectare(1000acre) site strategically located at Bandar Seri Iskandar ,Perak Darul Ridzuan . This campus is used as the experimental about the characterization of spatial variability of soil physical properties.

All the soil physical properties which are moisture content, soil bulk density, particle size distribution, organic content and specific gravity should be determined. With all of this, the characterization of spatial variability of soil physical properties can be determined. Thus, it can map the variation in soil physical properties at UTP campus. It also can evaluate the effect of land use changes on the variability of soil physical properties.

1.3 Objectives and Scope of Study

This project is essential to determine of characterization of soil physical properties at UTP campus. The main objectives of this research are:

1. To characterize spatial structure of soil physical properties under tropical climate in terms of semivariogram parameters.
2. To map the variation of soil physical properties in the study area.
3. To evaluate the effect of land use changes on the variability of soil physical properties.

This project also concentrate on the optimum size of spatial grids for distributed parameter hydrological model (Anctil et al., 2002), estimating point or spatially averaged values of soil properties that using kriging technique (e.g. Bardossy and Lehmann, 1988) and in designing sampling networks and improving their efficiency (e.g. Prakash and Singh, 2000).

Therefore, a field work and laboratory test needs to be done to achieve this entire objective.

CHAPTER 2

LITERATURE REVIEW/ THEORY

2.1 Theory

Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristics and precludes characterization of soil hydrological response. Recently, one of the major issues that has been increasing concern about how to estimate attribute of spatially varying of soil physical properties.

There are several form analysis that are important for characterization of spatial structure of soil engineering properties: (1) to determine the optimum size of spatial grids for distributed parameter hydrological models [Anctil et al., 2002], (2) estimating point or spatially averaged values of soil properties using kriging methods [Bardossy and Lehmann, 1998], (3) in designing sampling networks and improving their efficiency [Prakash and Singh, 2000].

The experiment of the spatial variability of soil physical properties are already been made by Rezaur et al., 2004 at USM campus. The semivariogram and statistical parameters has been characterized the spatial variability of soil physical properties. From the experimental they did, larger CV's (coefficient of variation) and sill (the total variance) for soil fines and moisture content indicates irregular distribution of these two properties compared to other soil properties [6].

Both of land disturbances and topographic conditions contributed to the variability of soil properties. However the semivariogram model parameter showed relatively poor fit to the data as judge from the low r^2 due to the fact that the number of sampling points selected was less relative to the extent of the area studied.

The change of land use pattern did not affect CV for soil pH and organic matter, but increased CV for soil available K and decreased CV for soil available P[10].

2.1.1 Bulk Density

Hernanz, 2000, discussed an empirical model to predict soil bulk density profiles in field conditions using penetration resistance, moisture content and soil depth. From the study it shows the bulk density of the soil expresses the relationship between its mass and the volume it occupies.

This parameter indirectly reflects the structural condition and compactness of the soil. Knowing the value of this parameter, porosity and air-filled porosity can be calculated. Likewise, it allows gravimetric moisture content to be put in terms of volumetric moisture, this in turn allowing insight to be gained into the water storage profile of the soil. Soil bulk density is measured using both direct and indirect methods.

The former are used to determine the value of a given mass of soil and the volume it occupies. Measurement of these two variables may be accomplished with the help of cylinders of a known volume, such as the Brandfield cylinder or the Uhland equipment developed by Utah State University.

These methods are quite straightforward but pose numerous disadvantages: they are laborious to use; a time elapses between field soil sampling and determination of the bulk density value in the laboratory; and they are highly susceptible to errors during sample extraction, transport and handling in the laboratory. The indirect methods are based on measuring the effect produced by the soil on the photons of gamma radiation emitted by a radioactive isotope. Calibration is required to empirically relate these effects to bulk density.

Available gamma-ray equipment operates by backscattering or by transmission. Both types of gamma-ray devices are costly and must be operated by nuclear safety trained personnel; preparation of the boreholes for insertion of the radioactive source and receiver is time-consuming and laborious; frequent calibrations are required; reading is slow; and it is necessary to know the soil moisture content.

Bulk density measurements are more accurate with transmission gauges than with backscattering gauges, and this accuracy also depends on the texture of the soil, since with clay and sandy soils the values of bulk density obtained using such equipment are similar to those obtained with the cylinder, this not being the case for loamy soils . Simultaneous measurement of bulk density and soil moisture content may be achieved using the double-energy gamma transmission gauge [4].

2.1.2 Moisture Content

Soil moisture is the key defining variable that integrates all components of the surface energy balance and as such is of major importance to climate models and their surface schemes (Rodriguez-Iturbe and Rinaldo, 1997). Furthermore understanding of soil moisture balance and its variability (spatial and temporal) is instrument qualifying the linkage between a region hydrology, ecology and physiography (geology).

Means, the spatial patterns and temporal variability of soil moisture will be consequence (and to some extend a controlling factor) of the area's vegetation and physiography (Rodriguez-Iturbe, 2000) [7].

2.1.3 Particle size distribution

Igathinathane et at, 2000, discussed machine vision based particle size and size distribution determination of airborne dust particles of wood and bark pellets. This study shows assessment of particle size and size distribution of dust, an essential first stage measurement, can be obtained utilizing several methods such as the basic mechanical sieving, and advanced light scattering, acoustic spectroscopy, and laser diffraction methods.

Machine vision is another approach to measure the size of particulate material, and image processing techniques were actually used for calibrating the aforementioned advanced instruments.

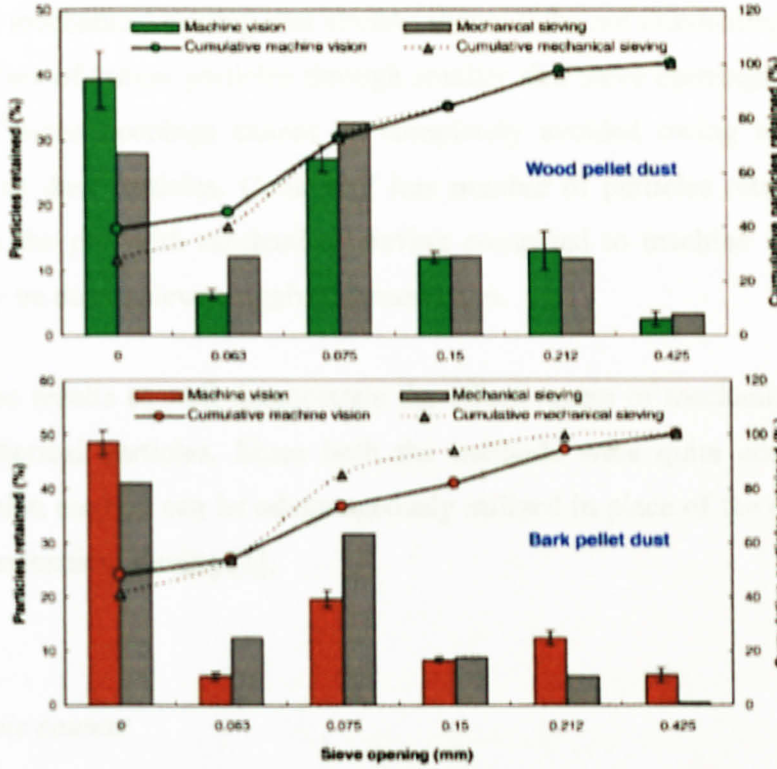

Figure 1: The comparison between experimental mechanical sieving and machine vision analysis.

Particle size distribution analysis from the two methods in the form of percentages of particles retained on sieves and cumulative particles retained showed comparable results (Fig. 1). In the absence of a standard reference method, it is not possible to decide which method is superior; however, Fig. 1 may serve to spot excessive departure (if present) between methods studied.

The observed deviations can be attributed to the differing mechanisms of particle separation and grouping between the methods. Mechanical sieving is essentially a width-based separation, while the present machine vision is truly length-based separation.

The mechanical sieving was already shown to be not eliminating the "falling-through" effect of longer particles through smaller size sieve openings . In addition, clogging of sieve openings cannot be completely avoided owing to electrostatic forces of fine dust particles. Consistent less number of particles retained for both materials in the pan with mechanical sieving compared to machine vision method (Fig. 1) may be due to sieve clogging phenomenon.

These results as well demonstrate the effectiveness of mechanical sieving of uniform spherical particles. Since both the methods were quite comparable, the machine vision method can be advantageously utilized in place of the expensive and laborious mechanical sieving [1].

2.1.4 Organic content

As reported by Shanju et al, 1999 in their study for the organic matter content of street dust in Liverpool, UK, and its association with dust magnetic properties. The dust organic matter level ranges from 1.0 to 10.1%. After eliminating six outliers, it ranges between 1.0 and 7.0% (average 4.0%, standard deviation 1.3%). No outlier in the surface soil samples is detected using the boxplot analysis.

The organic matter content of surface soil is between 3.4 and 8.6% (average 5.6%, standard deviation 1.8%). It seems that the organic matter content of dust is lower than that of soil, but the comparison is inconclusive because of the small number of soil samples.

Fergusson and Ryan (1984) estimated the organic matter content of street dust samples from different city types, ranging from 3.5 to 18.3%, by ignition at 500°C for 16 h. Al-Chalabi and Hawker (1996) reported a mean organic matter content of 4.1% in their samples (ignition at 500°C for 12 h).

Their results may overestimate the organic matter content due to the high ignition temperature (>400°C). Hildemann et al. (1991) showed a high level (17%) of organics in their fine particulate road dust samples [9].

2.1.5 Specific Gravity

Julian et al, 2008 was discussed the determining the specific gravities of coarse aggregates utilizing vacuum saturation approach. Vitton et al. investigated the applicability of the automated helium pycnometer in aggregate specific gravity analysis in geotechnical engineering.

The research targeted how to best measure the specific gravity of highly absorptive coarse aggregates. This was necessitated by the discovery that the conventional 24 ± 4 h failed to satisfy the full absorption potential of highly absorptive aggregates. Helium gas, on the other hand, can more easily absorb into a material's effective pore space.

A helium pycnometer uses the ideal gas law, $PV = nRT$, to determine the volume of a material based on pressure measurements of helium gas. By knowing the dry mass of the aggregate, the specific gravity of the aggregate can be determined. Another alternative Vitton et al. explored was the use of the automated envelope density analyzer.

This device determines the bulk volume or envelope volume of a sample by measuring the volume of a fine-grained material in a cylinder, and then again measuring the volume of the fine-grained material plus the sample. By finding the difference in volume between the two measurements, the bulk volume of the sample can be calculated and the bulk specific gravity determined.

The findings concluded that the helium pycnometer can be used to automate the testing of coarse aggregates to determine apparent specific gravity while the envelope density analyzer is applicable for specific gravity measurement of coarse aggregates. A combination of the helium pycnometer and the envelope density analyzer can be used to calculate the absorption, and bulk specific gravity (SSD) [5].

2.1.6 Geostatistic analysis

Geostatistics is a branch of applied statistics developed by George Matheron of the Centre de Morophologie Mathematicque in Fontainebleau, France. The original purpose of geostatistics centered on estimating changes in ore grade within a mine. However, the principles have been applied to a variety of areas in geology and other scientific disciplines.

A unique aspect of geostatistics is the use of regionalized variables which are variables that fall between random variables and completely deterministic variables. Regionalized variables describe phenomena with geographical distribution (e.g. elevation of ground surface) the phenomenon exhibit spatial continuity; however, it is not always possible to sample every location.

Therefore, unknown values must be estimated from data taken at specific locations that can be sampled. The size, shape, orientation, and spatial arrangement of the sample locations is termed the support and influences the capability to predict the unknown samples. If any of these characteristics change, then the unknown values will change.

The sampling and estimating of regionalized variables are done so that a pattern of variation in the phenomenon under investigation can be mapped such as a contour map for a geographical region.

2.1.7 *Semivariance*

Semivariance is a measure of the degree of spatial dependence between samples. The magnitude of the semivariance between points depends on the distance between the points. A smaller distance yields a smaller semivariance and a larger distance results in a larger semivariance.

The plot of the semivariances as a function of distance from a point is referred to as a semivariogram. The semivariance increases as the distance increases until at a certain distance away from a point the semivariance will equal the variance around the average value, and will therefore no longer increase, causing a flat region to occur on the semivariogram called a sill.

From the point of interest to the distance where the flat region begins is termed the range or span of the regionalized variable. Within this range, locations are related to each other [2].

2.1.8 *Kringing*

Kriging is the estimation procedure used in geostatistics using known values and a semivariogram to determine unknown values. It was named after D. G. Krige from South Africa. The procedures involved in kriging incorporate measures of error and uncertainty when determine estimations [2].

CHAPTER 3

METHODOLOGY

The methodology for this project is to characterize spatial structure of soil physical properties under tropical climate in terms of semivariogram parameters, to map the variation in soil physical properties in the area and to evaluate the effect of land use changes in the variability of soil physical properties.

This project will be done by doing the study area, laboratory analysis, and statistical and geostatistical analysis.

3.1 The study area

The study was conducted in the University Technology Petronas(UTP) which located in Bandar Seri Iskandar that established on January 10,1997.The campus area is 400 ha (1000acres).

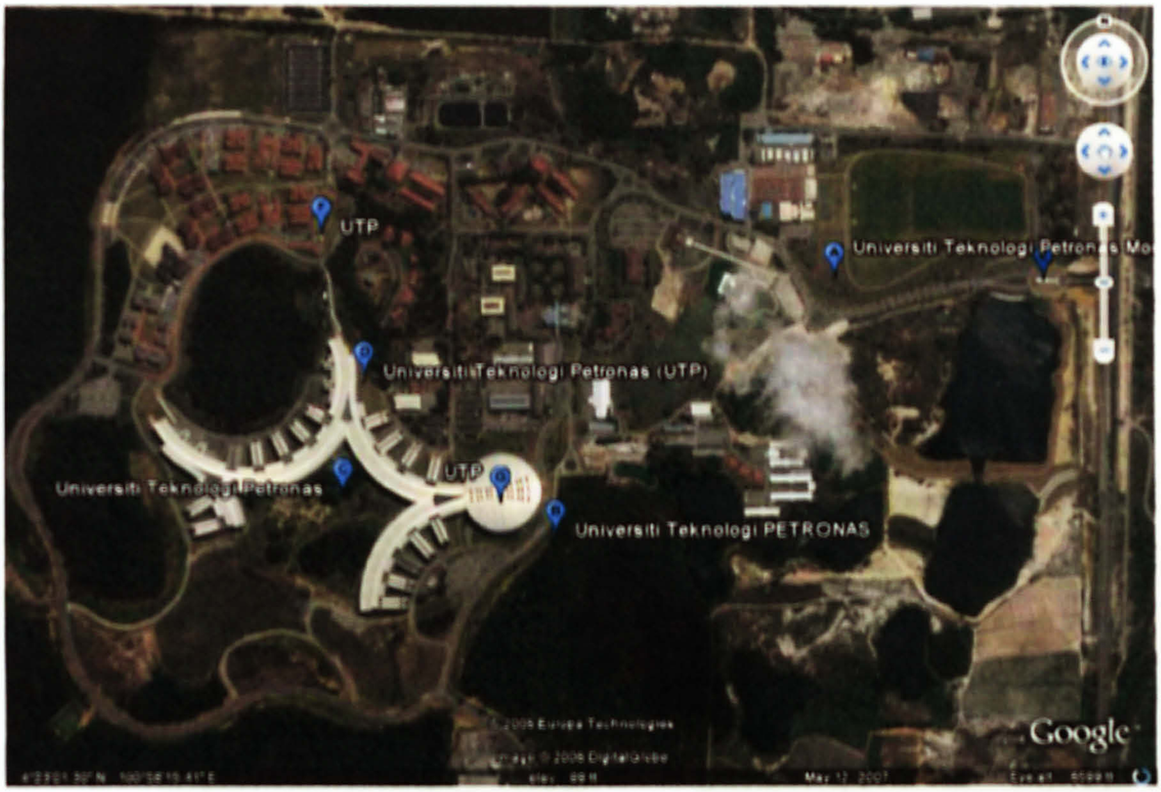

Figure 2: Topography map of UTP campus

3.2 Soil sampling and laboratory analysis

The grid sampling method will be used for this study on the premise that grid sampling reduces the possibility of uneven clustered samples. The campus will be divided by a number of regular geo-grids. Soil samples were collected at each grid-note.

The sampling location which fell on paved area or on buildings or where the sampling location was inaccessible (wet areas) were omitted. In certain occasion where the sampling location fell at the corner of a building, soil samples were collected from the adjacent ground.

During field sampling the grid-note locations were established by a portable Global Positioning System (GPS) (see Figure 3) unit with an error of ±1m.Fifty soil samples were collected during the sampling program (Figure 4).

Figure 3: GPS equipment and the close up view of the GPS equipment

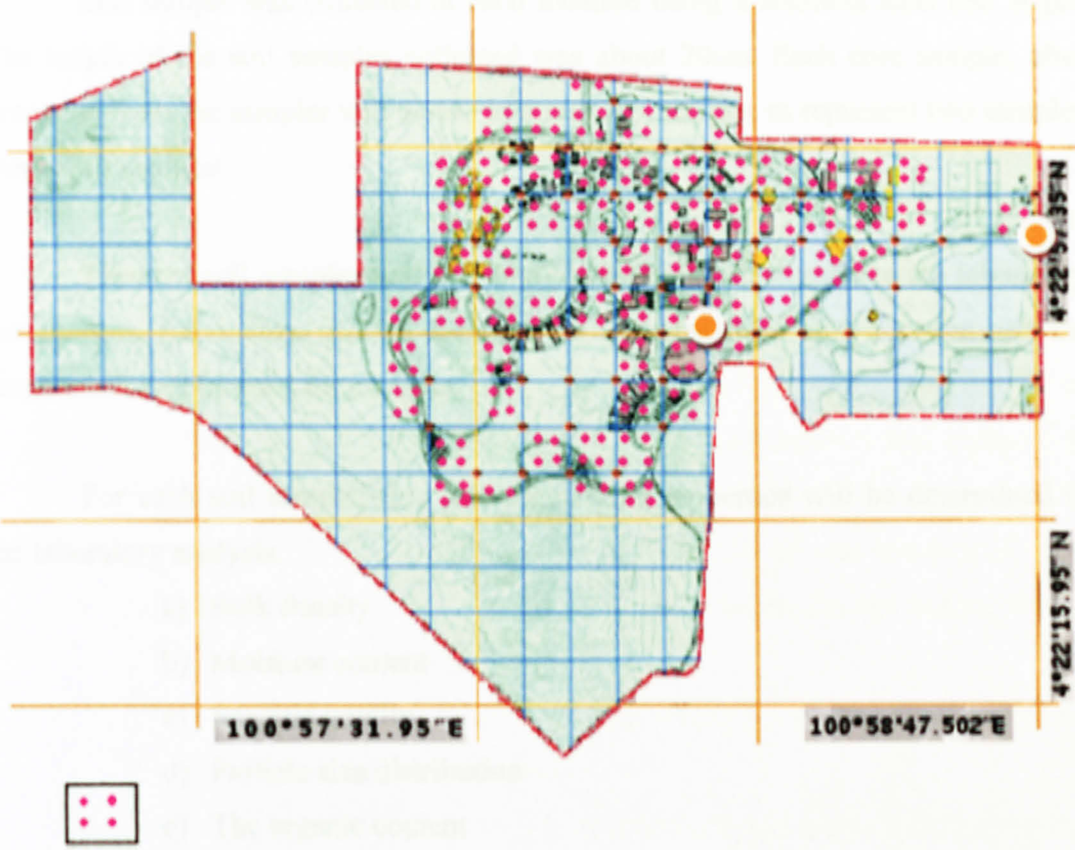

Figure 4: The geo-grid sampling location

Where :-

is point that GPS located

is point that soil sample taken

Soil sample was collected at each location using a stainless steel soil auger. The length of the soil samples collected was about 20cm. Each core sample, after extrusion from the sampler will divide into two sub-samples to represent two samples from each location.

Then the soil samples will seal into plastic bags and transfer to the laboratory for analysis. Laboratory will be done on two samples from each location and the mean result will be used for analysis.

For each soil sample, five soil engineering properties will be determined in the laboratory analysis:

a) Bulk density
b) Moisture content
c) Specific gravity
d) Particle size distribution
e) The organic content

3.2.1 *Bulk Density*

The soil bulk density can be determined from the ratio of sample mass and the volume. The sample volume can be known by measuring sample length and cross sectional area and the sample mass will be obtained from the dry weight of the sample subjected to oven drying at 110°C for 24 hours.

The bulk density can be calculated:

$$\text{Bulk density} = \frac{\text{Mass of soil (g)}}{\text{Volume of cylinder (cm}^3\text{)}}$$

3.2.2 Moisture Content

The soil moisture content can be determined from the difference between the wet weight (field sample) and dry weight (subjected to oven drying at 110°C for 24 hours) of the sample and expressed as a percentage of the dry weight of the sample. The procedure for determination of moisture content is:

1) Clean and dry the moisture content tin and weigh it to the nearest 0.01g (m1). Take a sample of at least 30g of soil, crumble and place loosely in container, and replace the lid. Then weigh the container and contents to the nearest 0.01g (m2).
2) Remove the lid, and place the container with its lid and contents in oven and dry at 105°C to 110°C for a period of 24 hours. Do not replace the lid while the sample is in the oven.
3) After drying, remove the container and contents from the oven and place the whole in the desiccator to cool.
4) Replace the lid and then weigh the container and content to the nearest 0.01g (m3).
5) Calculate the moisture content of soil specimen:

$$\text{Moisture content, } W = \frac{(m2 - m3)}{(m3 - m1)} \times 100\%$$

Where:-

m1 is the mass of container (in g)

m2 is the mass of container and wet soil (in g)

m3 is the mass of container and dry soil (in g)

3.2.3 Specific Gravity

Figure 5: Specific gravity equipment

The sample specific gravity can be determined by the large pyknometer method that suitable for soils containing particles up to medium gravel size. Sample specific gravity data are used in hydrometer analysis but are not intended for spatial variability analysis.

The procedure of specific gravity (Figure 5) is:

1) Take a sample of soil about 1.5kg and sieve the sample. Break down the coarse particles retained on a 20mm test sieve to less than that size.
2) Divide the sample into 2 specimens, each weighing 400g by riffling.
3) Put these specimens into the oven for drying at 105°C - 110°C and then store the specimens in an airtight container until required.
4) Clean and dry the pyknometer and weigh the whole assembly to the nearest 0.5g (m1).
5) Remove the screw top and transfer the first specimens from its sealed container directly into the jar.

6) Weigh the jar and its content and the screw-top assembly to the nearest 0.5g (m2).

7) Add water at a temperature of within ±2°C of the average room temperature during the test to about half fill of the jar. Stir the mixture thoroughly with the glass rod to remove air trapped in the soil.

8) Fit the screw cap assembly and tighten it so that the reference marks coincide. Fill the pyknometer with water.

9) Agitate by shaking the pyknometer. Allow air to escape and froth to disperse. Leave the pyknometer standing for at least 24hour at room temperature content within ±2°C.

10) Top up the pyknometer with the water so that the water surface is flush with the hole in the conical cap. Make notes that air bubbles or froth are not trapped under the cap.

11) Dry the pyknometer on the outside and weigh the whole to the nearest 0.5(m3).

12) Empty the pyknometer, wash it thoroughly and fill it completely with water at room temperature. Make sure that the reference marks on the screw cap coincide, that no air bubbles are entrapped, and that the water surface is flush with the hole in the conical cap.

13) Dry the pyknometer on the outside and weigh to nearest 0.5g (m4).

14) Repeat step 4-12 by using second specimen of the same soil so that the two values of particle density can be obtained. If the results differ more than 0.05M/m³, repeat the test.

The specific gravity, ρs can be calculated:

$$\rho s \text{ (in Mg/m}^3\text{)} = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)}$$

Where:-

m1 is mass of pyknometer + cap assembly (g)

m2 is mass of pyknometer + cap + soil (g)

m3 is mass of pyknometer + cap + soil + water (g)

m4 is mass of pyknometer + cap + water (g)

3.2.4 Particle Size Distribution

The particle size distribution is determined using both, mechanical sieving and hydrometer analysis. Then the results of the two analyses are then combined to produce the complete particle size distribution of the soil samples. The fine content are used for statistical and geostatistical analysis.The procedure of particle size distribution is:

1) Weigh the oven dried sample to 0.1% to its total mass (m1).
2) Stack 8 numbers of test sieves on the mechanical shaker with the largest size test sieve appropriate to the maximum size of material present at the bottom of the stack followed by the smaller size test sieves and a receiver at the bottom of the sack.
3) Place the sample on the top sieve and cover the sieve with a lid. Agitate the test sieves on the mechanical sieve shaker for 5 minute. Weigh the amount retained on each of the test sieves to 0.1% of its total mass.

Figure 6: Mechanical Sieving equipment

3.2.5 OrganicContent

The sample organic content is determined from the difference between the weight of the oven dried (at 110°C for 24hours) sample and the weight of the sample subjected to ignition in a muffler furnace at 440°C for 4 hours and expressed as a percentage of the oven dry weight of the sample.

Figure 7: The muffler furnace at 440°C

The organic content can be calculated:

$$\text{Organic content, \%} = \frac{(m2-m1)-(m3-m1)}{(m2 - m1)} \times 100$$

Where:

m1 = mass of container

m2 = mass of dry soil + container at 110°C

m3 = mass of burn soil + container at 440°C

3.3 Statistical and Geostatistical Analysis

The results of the laboratory tests on soil engineering properties are subjected to two types of analysis:

i. Normal statistical
ii. Geostatistical analysis

3.3.1 Normal Statistical analysis

Normal statistical analysis included determination of maximum, minimum, mean, standard deviation, and the coefficient of variation of soil engineering properties over the study area.

3.3.2 Geostatistical analysis

Geostatistical analysis included examining spatial variability nature of the soil engineering properties by determining semivariogram parameters namely the sill, nugget, and the range, established best fitted semivariogram models for the soil properties, and computing maps of distribution of soil engineering properties over the study area using the kriging method. Kriging allow the estimation of spatially correlated data and are superior to other commonly used interpolation techniques such as Inverse Distance Weighting (IDW) and Normal Distance Weighting (NDW). Geostatistical characterization of the data is performed by using GS+ (Gamma Design Software, Plainwell, MI, USA).

The semivariance was estimated for all the four soil engineering properties. The semivariance is defined as (Goovaerts, 1977):

$$\hat{\gamma}(h) = \frac{1}{2} \cdot \frac{1}{n(h)} \sum_{i=1}^{n(h)} (z(x_i + h) - z(x_i))^2$$

Where:

$\gamma(h)$ = the semivariance,

h i = the lag,

$N(h)$ i= the total number of sample couples separated by the lag interval h;

$z(x_i)$ = the measured sample value at point (x_i)

$z(x_i+h)$ = the measured value at point (x_i+h).

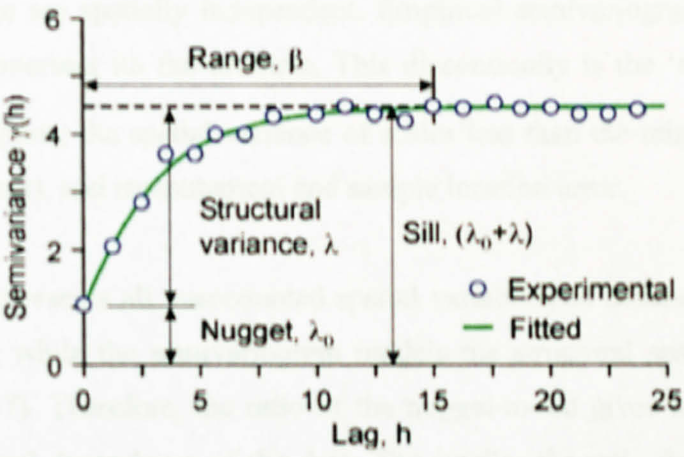

Figure 8: Schematic diagram of a semivariogram and its parameters

A property is called spatially dependent or auto correlated if the probability of similar data values is higher for neighboring sample points than for points far from each other (Warrick et al., 1986). Thus, $z(x_i)$ correlates to the neighboring $z(x_i+h)$, with h being the *lag*, between $z(x_i)$ and $z(x_i+h)$.

The correlation between $z(x_i)$ and $z(x_i+h)$ expresses the spatial structure of a variable of interest (Isaaks and Srivastava, 1989). The semivariogram displays the change in semivariance between sample points with increasing lag. Figure 2 schematically illustrates an experimental and fitted semivariogram with parameters. The semivariance rises with increasing lag then levels off.

The lag, at which the plateau is achieved, is called the 'range' β, and the semivariance value of the plateau is called the 'sill' $(\lambda_0+\lambda)$ (Figure 2). Points within the range are considered to be spatially or temporally auto-correlated, while points outside the range are spatially independent. Empirical semivariograms seldom pass the origin, but intersect ith the ordinate. This discontinuity is the 'nugget' λ_0, and consists of two parts; the spatial variance of scales less than the minimum sampling distance (if present), and measurement and sample location error.

The nugget represents all unaccounted spatial variability at distances smaller than the smallest lag while the semivariogram models the structural spatial dependence (Goovaerts, 1997). Therefore, the ratio of the nugget-to-sill gives a measure of the spatial or temporal dependence of the data. The smaller the ratio the stronger is the spatial dependence. Calculation of semivariance assumes stationarity. The existence of a sill in a semivariogram is an indication thaw t the process is stationary (Western et al., 1998).

Five different models were examined to fit the semivariance data. These include the spherical, lin-ear, linear-sill, exponential, and gaussian model. Optimal models were determined by examining the fit of the model to the semivariogram as judged by the coefficient of determination r^2 and RSS (residual sums of squares) values.

The two models that best fit the semivariograms of soil engineering properties data were spherical model and the exponential model, which are defined respectively by:

$$\gamma(h) = \lambda_0 + \lambda[1.5(h/\beta) - 0.5(h/\beta)^3] \qquad \text{for } h \leq \beta$$

$$\gamma(h) = \lambda_0 + \lambda \qquad \text{for } h > \beta$$

$$\gamma(h) = \lambda_0 + \lambda\,[1-\exp(-h/\beta)]$$

For each of these models, λ_0 represents the nugget variance, attributable to variance due to scales smaller than the sampling distance plus measurement errors. The structural variance, λ, is the variance attributable to the separation distance between observations.

The sum of λ_0 and λ is an estimate of the total variance. For the spherical model, β is the range and is the maximum separation distance for which sample pairs remain correlated. For the exponential model, β is not the range, but a parameter used in the model to provide the range. The range of the exponential model can be estimated as 3β (Isaaks and Srivastava, 1989).

3.4 Tools/Equipment Required

The tools and equipments which are required in this Final Year Project are:

i. GPS(Global Positioning System)
ii. Hoe
iii. Scope and Trowel
iv. Polythine bags
v. Mufler furnace
vi. Pyknometer
vii. Oven
viii. Desiccator
ix. Mechanical sieving equipment
x. Cylinder
xi. GS+ Software
xii. Surfer Software
xiii. Digitizing Software

3.5.1 Gantt Chart and Milestone of Project

The Gantt chart and milestone of the project is attached in the attachment behind (refer Appendix A1 and A2).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Geo-Grid Sampling Locations

The CorelDRAW 9 software is used in doing the geo-grid sample location. After the geo-grid location is determine by choosing the intersection of the grid line, the GPS is done to determine the geo-grid sampling location (Latitude and Longitude). 2 points were selected to be the control point and the points were plotted into UTP Campus map and a geo-grid was designed on the map (Figure 4.1.1)

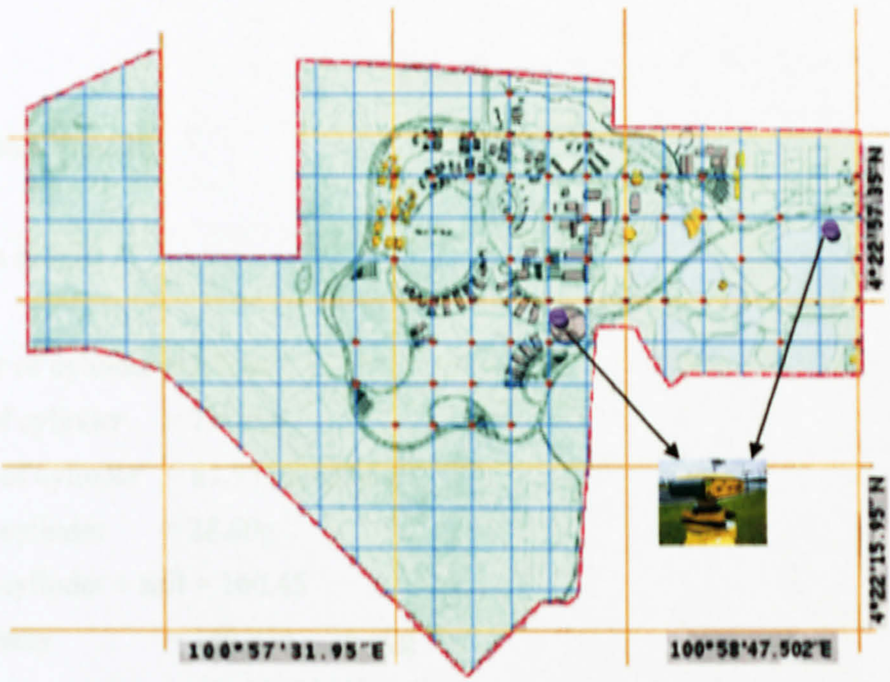

Figure 9: Geo-grid sampling location and location of the control point for GPS instrument setup

The result of the GPS data collection;

Point	Latitude (N)	Longitude (E)
Main Gate	4°23'07.70531"N	100°58'47.47385"E
Chancellor Hall	4°22'57.35198"N	100°58'12.63480"E

Table 4.1.1: Result of GPS Data

Both points are use as the control point that were used to plot on the UTP Campus map to design the geo-grid sampling locations. The longitude and latitude for other sample location is determined by the interpolation method.

Then, the author will proceed onto the bulk density, moisture content, particle size distribution, specific gravity and organic content test and 55 samples were to be done.

4.2 Bulk Density

Based on sample 4,

Diameter of cylinder = 3.7cm
Height of cylinder = 7.62cm
Volume of cylinder = 81.93100853cm³
Mass of cylinder = 28.60g
Mass of cylinder + soil = 160.45

$$\text{Bulk density} = \frac{160.45g - 28.60g}{81.93100853cm^3}$$

$$= 1.609280813 \text{ gm/ cm}^3$$

4.3 Moisture Content

Based on sample 4,

Mass of container (m1) = 20.67g

Mass of wet soil + container (m2) = 60.15g

Mass of dry soil + container (m3) = 59.12g

Moisture content, W $= \frac{1.030g}{38.45g} \times 100\ \%$

$= 2.678803641\ \%$

4.4 Specific gravity

Based on sample 4,

Mass of jar + gas jar + plate (m1) = 543.93g

Mass of jar + gas jar + plate + soil (m2) = 820.07g

Mass of jar + gas jar + plate + soil + water (m3) = 1640.66g

Mass of jar + gas jar + plate + water (m4) = 1548.66 g

Specific gravity $= \frac{820.07g - 543.93g}{(1548.66g - 543.93g) - (1640.66g - 820.07g)}$

$= 1.499619854\ Mg/m^3$

4.5 Organic content

Based on sample 4,

Mass of container, a = 20.78g

Mass of oven dried soil + container (at 110°C), X = 50.8g

Mass of dry soil + container (at 440°C), Y = 48.6g

Percent of organic content, % = $\frac{(50.8g - 20.78g) - (48.6g - 20.78g)}{(50.8g - 20.78g)}$

= 7.328447702%

4.6 Particle Size Distribution

Based on sample 4,

Sieve size	Mass of sieve, g	Mass of sieve + soil, g	Mass retained, g (m)	Percentage retained, % ((m/602.45) x 100)	Cumulative Percentage Passing, %
3.35mm	484.57	494.2	9.63	1.598473	98.401527
2mm	380.99	494.2	113.21	18.7916	79.609927
1.18mm	425.91	492.83	66.92	11.10798	68.501947
600µm	406.27	476.21	69.94	11.60926	56.892687
425µm	369.67	489.35	119.68	19.86555	37.027137
300µm	356.03	400.21	133.32	22.12964	14.897497
212µm	339.67	405.58	65.91	10.94033	3.957167
150µm	269.22	279.01	9.79	1.625031	2.332136
63µm	326.43	338.91	12.48	2.071541	0.2606
Passing 63µm	245.47	247.04	1.57	0.260602	0.000002

Table 4.6.1: Particle Size Distribution

4.7 Statistical Analysis

The summary of normal statistics of the soil engineering properties obtained from 55 samples is shown in Table 1.The coefficient of variation (CV) is an indicator of variability. Among the four soil properties examined the organic content show the highest CV (58.31%), followed by moisture content (37.34%) and fine content (13.26%), while soil bulk density shows the lowest (9.47%) CV (Table 4.7.1)

The lowers CV for bulk densities are expected because the range over which soil density could vary is narrow compared to other soil properties.

Soil properties	N	Max.	Min.	Mean	SD	CV (%)
Fines (%)	55	94.4795	42.33171	75.945	10.06716	13.26
Moisture content (%)	55	32.18884	1.174706	16.52444	6.170696	37.34
Organic content (%)	55	27.54098	1.973684	12.68445	7.396276	58.31
Bulk Density (gm/cm^3)	55	1.611112	1.08628	1.368719	0.129666	9.47

Table 4.7.1: Sample size (N), maximum, minimum, mean, standard deviation (SD), Coefficient of variation (CV) of tested soil engineering properties

4.8 Geostatistical Analysis

The best fitted semivariogram model parameters are shown in Table 4.8.1. The best fitted semivariogram of different soil properties are shown in Figure 10, Figure 11, Figure 12, and Figure 13.

Thus, it is possible to examine the spatial structure and dependencies of the soil properties in terms of semivariogram parameters, the range, sill, nugget, and nugget-to-sill ratio after the semivariogram models and parameters for the soil properties are done.

Soil properties	Model*	Range (m)	Nugget (λ_0)	Sill (λ_0+λ)	Sv (%) (λ)	Ratio (%) $\lambda_0/(\lambda_0+\lambda)$
Fines (%)	E	150	58.9	262.7	203.8552	0.22421
Moisture content (%)	S	3735	19.1	79.9	60.8039	0.239049
Organic content (%)	S	380	8.6	53.38	44.78582	0.161109
Bulk Density (gm/cm³)	S	4110	0.008	0.0371	0.02886	0.215633

Table 4.8.1: Characteristics parameters of fitted semivariogram of soil engineering properties

Where:

E = Exponential;

S= Spherical;

Sv= Structural variance

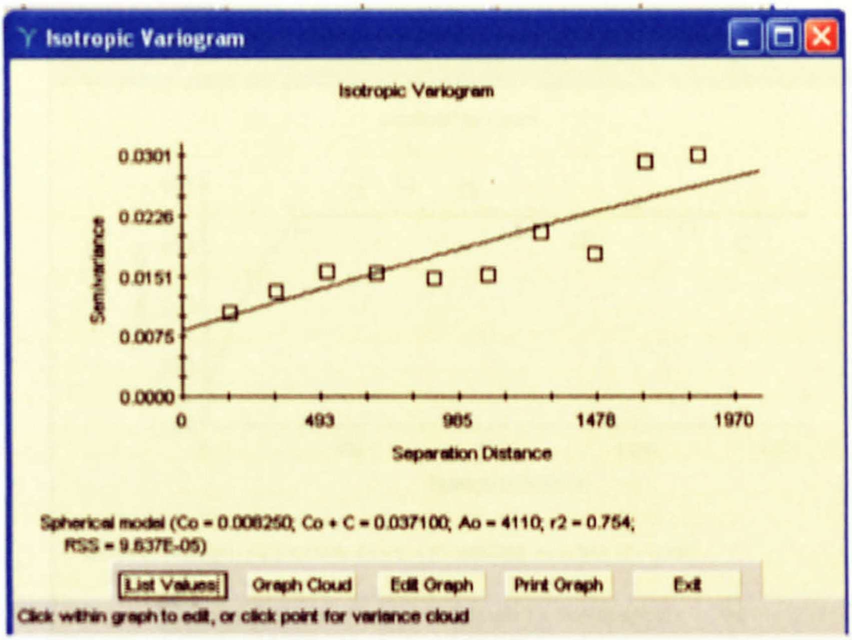

Figure 10: Semivariogram and fitted model of soil bulk density

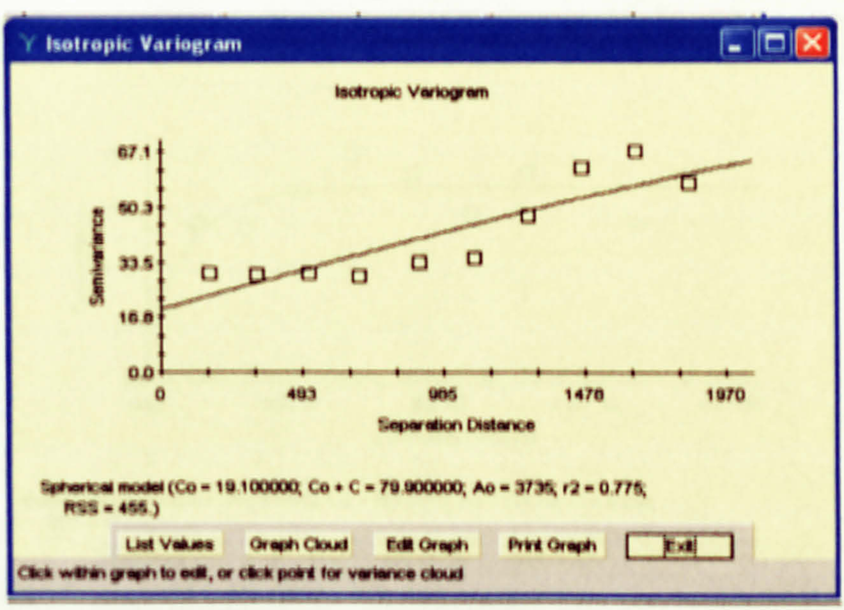

Figure 11: Semivariogram and fitted model of soil moisture content

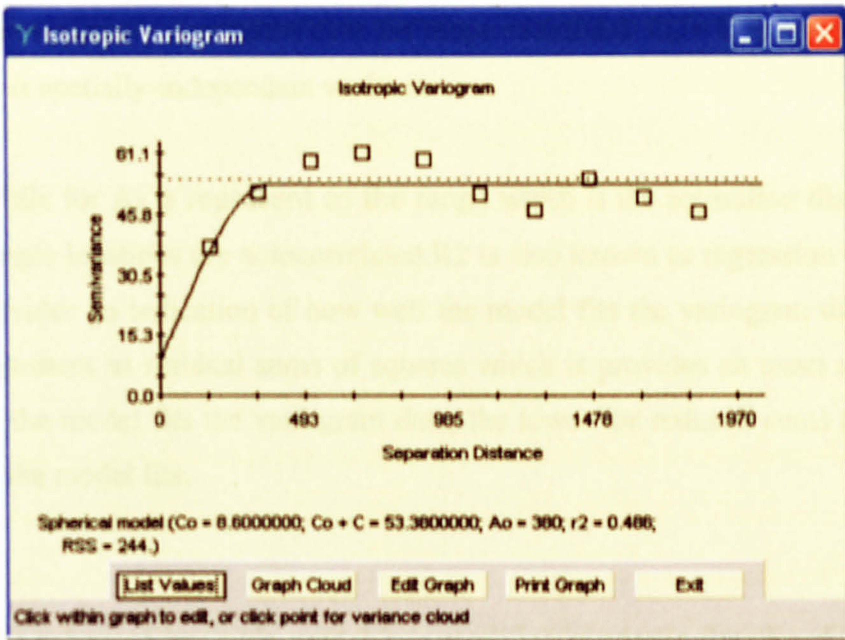

Figure 12: Semivariogram and fitted model of soil organic content

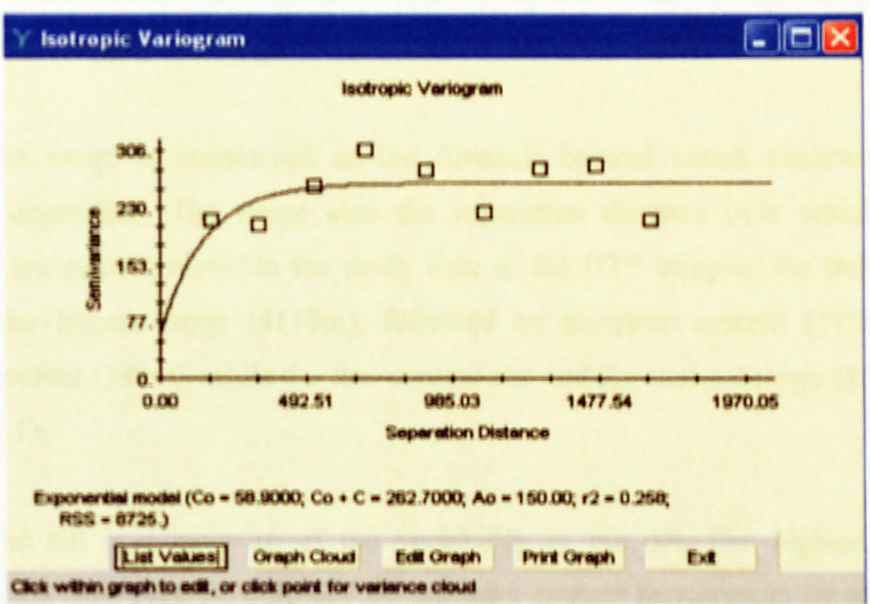

Figure 13: Semivariogram and fitted model of fines

From the Figure 10,11,12, and 13, C_0 is represent as the nugget which is variation not spatially dependent over the range examined. $C_0 + C$ is represent as the sill which is spatially-independent variance.

While for A_0 is represent as the range which is the separation distance over which sample locations are autocorrelated.R2 is also known as regression coefficient which provides an indication of how well the model fits the variogram data and the RSS is represent as residual sums of squares which is provides an exact measure of how well the model fits the variogram data; the lower the reduced sums of squares, the better the model fits.

The spherical isotropic model is a modified quadratic function for which at some distance range, pairs of points will no longer be autocorrelated and the semivariogram reaches an asymptote. While for the exponential isotropic model is similar to the spherical in that it approaches the sill gradually, but different from the spherical in the rate at which the sill is approached and in the fact that the model and the sill never actually converge.

The range is considered as the distance beyond which observations are spatially dependant. The range also the separation distance over which sample locations are autocorrelated.In the study area of the UTP campus, the bulk density showed the largest range (4110m), followed by moisture content (3735m), and organic content (380m), while the fine content showed the shortest range (150m) (see Table 4.7.1).

The sill is a measure of the variability in the data.The highest sill was observed for fine content followed by moisture content and organic content, while bulk density showed the lowest sill (Table 4.8.1).Therefore, in the study area large variability are associated with fine and moisture content while relatively low variability are associated with organic content and bulk density.

The nugget-to-sill ratio gives an indicator of the spatial dependency of the data.A variable is considered to have a strong spatial dependence if the ratio is less than 25%, and a moderate spatial denpendence if the ratio between 25% and 75%, and a weaj dependence for ratio >75% (Goderya et al.,1996). The nugget to sill ratio for all soil properties examined in the study ranged from 16% to 24% (<25%) (Table 4.8.1).Thus, it is indicating the strong spatial dependence.The strong spatial dependency of the soil engineering properties provides indication of the influence of intrinsic or extrinsic factors.

The nugget is measure of all unaccounted spatial variability at distance smaller than the smallest lag (160 m in this study) while the structural variance accounts for variation due to spatial autocorrelation. The relatively smaller nuggets for soil organic content and bulk density (Table 4.8.1 and Figure 10 and 12) suggest that less variation existed for these two soil properties at distances shorter than the smallest lag.

In contrast, the relatively larger nuggets for soil fine and moisture content compared to soil organic content and bulk density (see Table 4.8.1 and Figure 10,11,12, and 13) suggests that the variation of soil fines and moisture contents at distances shorter than the smallest lag are more than for organic contents and bulk densities.

4.9 Kring Spatial Soil Properties

The spatial distribution of soil properties for unsampled locations in the study area were obtained from interpolation between sampled location by the method of kringing, based on semivariograms of the soil properties at sampled locations.Figure 14,15,16, and 17 illustrate the spatial distribution of bulk density, moisture content, organic content, and fines respectively, over the study area.

These maps of spatial distribution of soil properties in conjuction with the site map (Figure 9) now allow examining the closeness of association between variation in soil properties and topographic conditions.

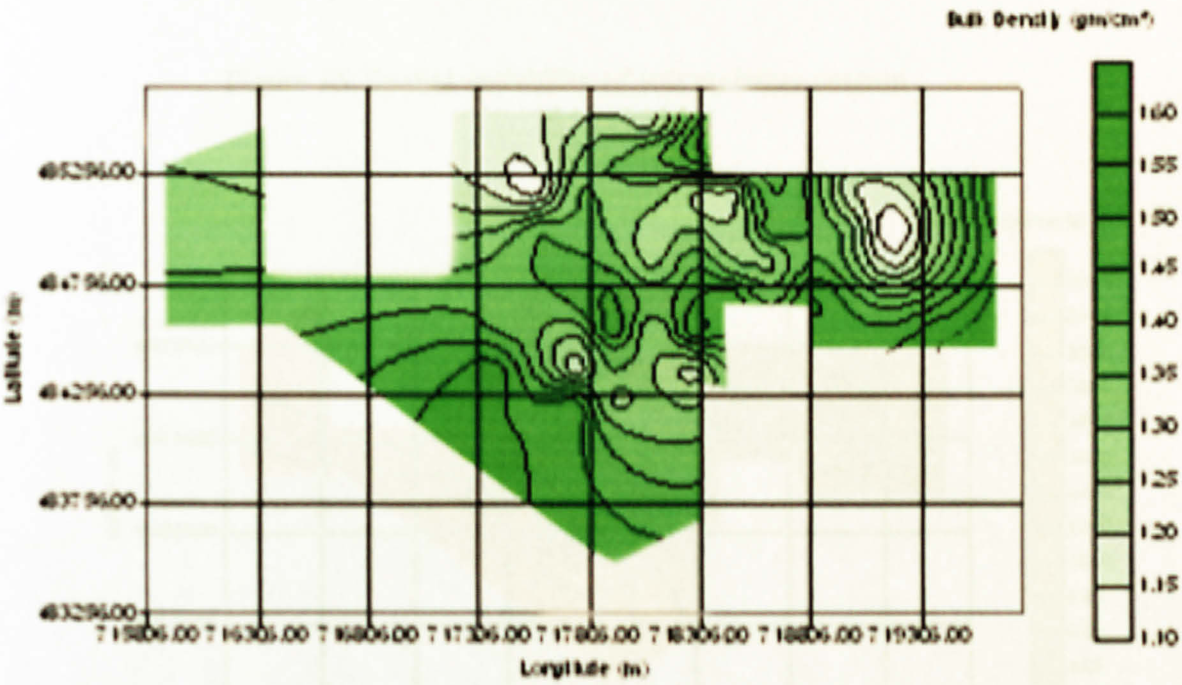

Figure 14: Spatial variability of soil bulk density

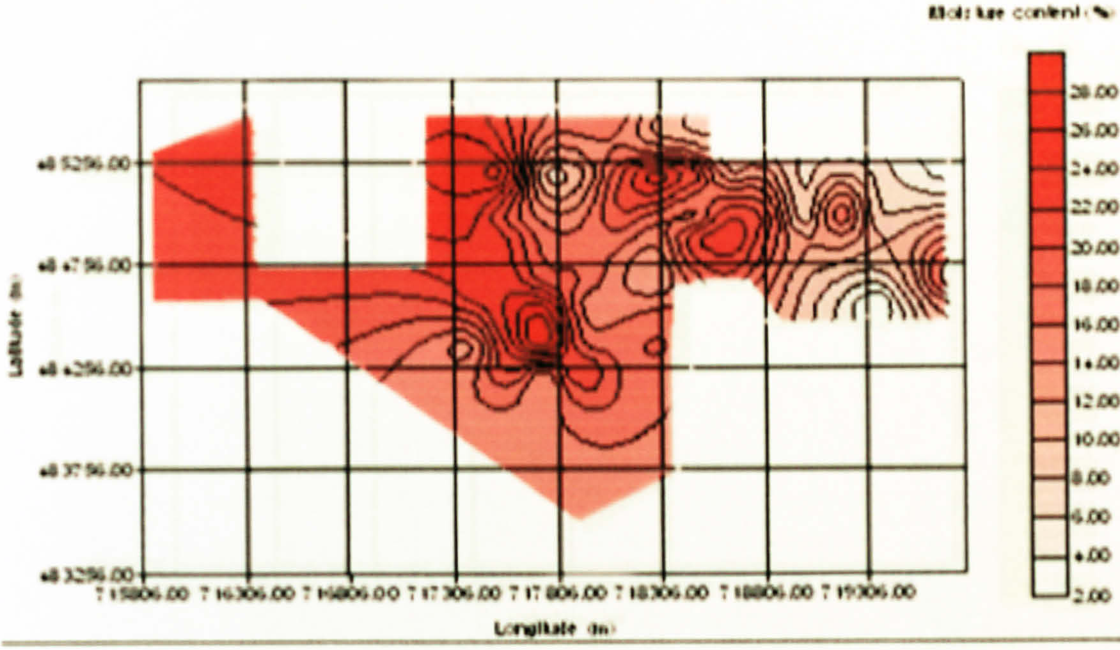

Figure 15: Spatial variability of soil moisture content

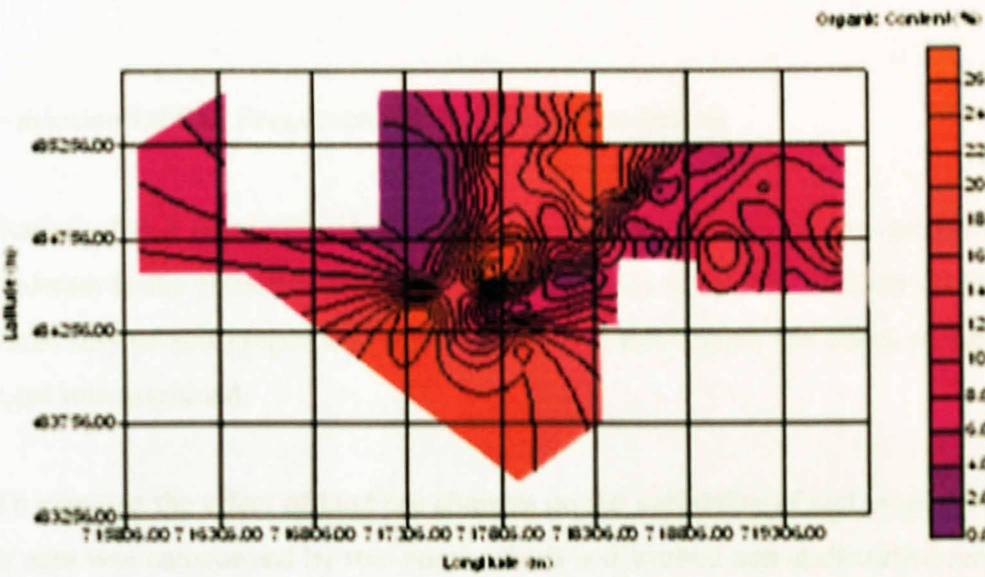

Figure 16: Spatial variability of soi organic content

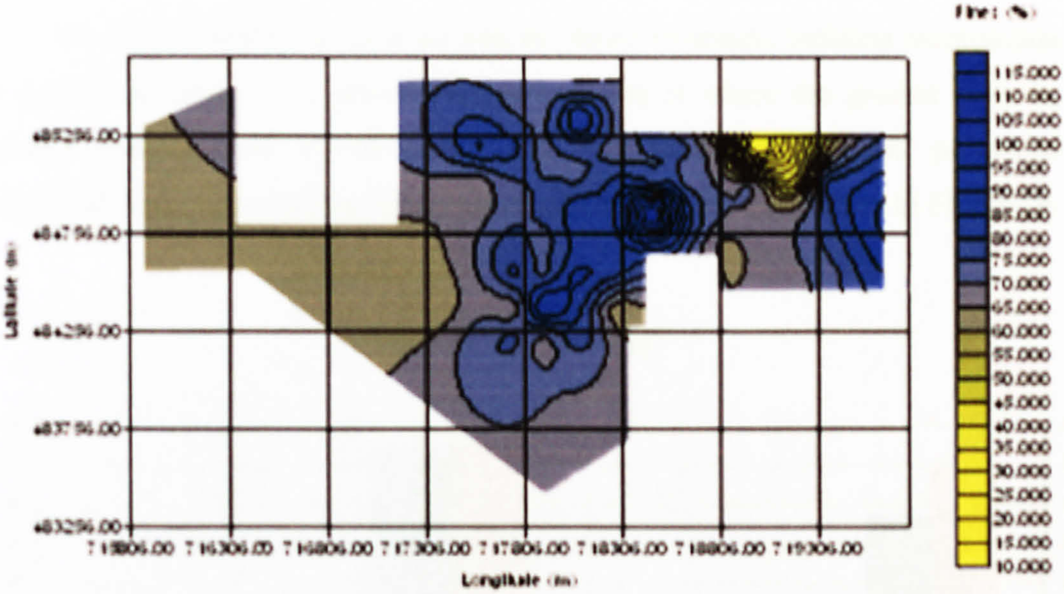

Figure 17: Spatial variability of soil fines

4.10 Variation Of Soil Properties On Land Use Conditions

Statistical and geostatistical characterization of the soil properties provided strong evidence to the existence of influence from intrisic to extrinsic factors on the spatial variability of soil properties.To investigate into this aspect, the effect of land use changes was examined.

To examine the effect of land use changes on the variability of soil properties, the study area was categorized by two zones which is disturbed and undisturbed area (refer Figure 4).

The disturbed zone is the zone with the forest clearance, building construction and ground alteration took place. Undisturbed area is where the ground is in its original condition such as the forest area. The mean of each soil properties investigated were computed for these two zones and compared as shown in Figure 18.

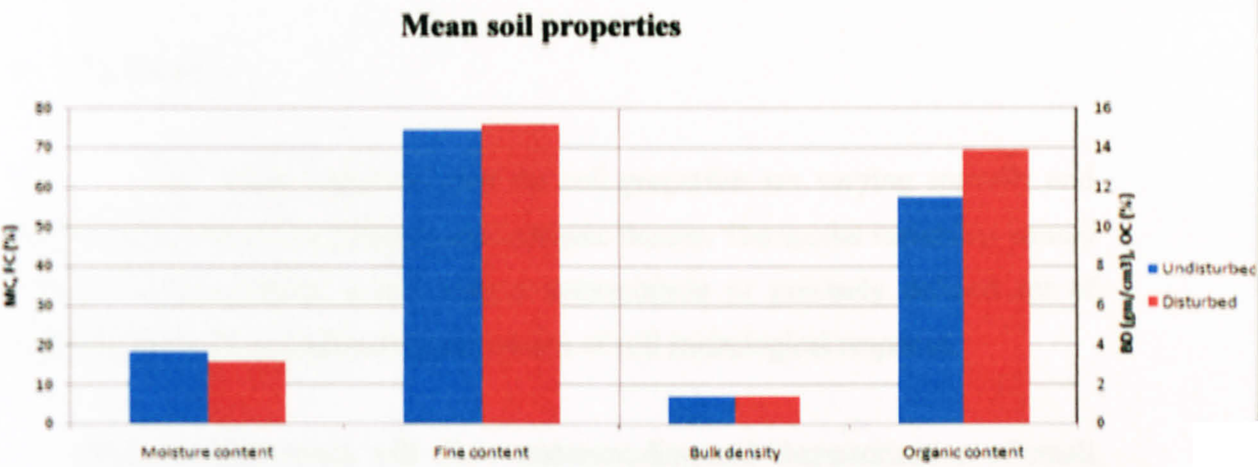

Figure 18: Effect of land use patterns on soil properties (MC: Moisture content; FC: Fine content; OC: Organic content; and BD: Bulk density)

Figure 18 indicates that the mean soil moisture content (MC) was higher in the undisturbed zones than compared to disturbed zones. However, the mean soil fine content (FC) and organic content (OC) were higher in the disturbed zones compared to undisturbed zones.

Thus it appears that the significant differences between soil engineering properties between the disturbed and forest zones are a consequence of disturbances cause by forest clearance and land alteration. It also appears that large variability of soil properties observed in the study area is probably a consequence of land use conditions.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The author concludes that the soil properties are varying spatially and both are influenced by the intrinsic and extrinsic factors. The spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristics and precludes characterization of soil hydrological response.

This proposed study will allow understanding and characterization of small scale spatial variability nature of soil physical properties characteristics in University Technology of PETRONAS (UTP) campus area with a statistic and geostatistic method. This study will find out and characterize spatial structure of soil physical properties characteristics of soil under tropical climate in terms of semivariogram parameters.

By using geostatistic, it can indicate distance of where the correlated data occurred, the variability of the data and also the degree of the spatial dependency. Besides, it also can allows mapping of the spatial distribution and the normal statistics will helped in identifying causes of the variability in the soil engineering properties.

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APPENDICES

Appendix A: Gannt Chart Suggested Milestone For The First Semeter Of Final Year Project

Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of project topic														
Research for prelimenary report														
- Literature Review														
Project work														
Study & Decide 50 location														
Submission of Preliminary & Progress Report								•						
Project work continue														
-Soil sampling														
-Laboratory analysis														
Submission of Interim Report Final Draft													•	
Oral Presenatation														•

Appendix B: Suggested Milestone For The Second Semeter Of Final Year Project

Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project work continue														
-Soil sampling														
-Laboratory analysis														
Submission of Progress Report 1				•										
Submission of Progress Report 2								•						
Project Work Continue														
-Statistical & Geostatistical analysis														
- Preparing poster, oral and disserttion report														
Poster exhibition										•				
Submission Of Dissertion (soft bound)												•		
Oral Presentation													•	
Submission Of Dissertion (hard bound)														•

Appendix C: Data of bulk density

Sample	Longitude(E)	Latitude(N)	Mass(gm)	Volume	Bulk density
1	100° 58' 47.502"	4° 22' 52.175"	129.84	81.93100853	1.584747977
2	100° 58' 47.502"	4° 22' 57.35"	130.44	81.93100853	1.592071211
3	100° 58' 47.502"	4° 23' 2.525"	124.73	81.93100853	1.522378428
4	100° 58' 47.502"	4° 23' 12.875"	131.85	81.93100853	1.609280813
5	100° 58' 35.878"	4° 22' 52.175"	125.56	81.93100853	1.532508903
6	100° 58' 35.878"	4° 23' 7.7"	103.06	81.93100853	1.257887604
7	100° 58' 30.07"	4° 23' 2.525"	94.67	81.93100853	1.155484373
8	100° 58' 30.07"	4° 23' 7.7"	89	81.93100853	1.086279805
9	100° 58' 24.254"	4° 22' 57.35"	116.12	81.93100853	1.417290011
10	100° 58' 24.254"	4° 23' 7.7"	108.31	81.93100853	1.321965907
11	100° 58' 24.254"	4° 23' 12.875"	97.6	81.93100853	1.191246169
12	100° 58' 18.442"	4° 22' 57.35"	124.95	81.93100853	1.525063614
13	100° 58' 18.442"	4° 23' 7.7"	114.4	81.93100853	1.396296739
14	100° 58' 18.442"	4° 23' 12.875"	112.8	81.93100853	1.376768113
15	100° 58' 12.63"	4° 22' 57.35"	112.1	81.93100853	1.368224339
16	100° 58' 12.63"	4° 23' 2.525"	104	81.93100853	1.269360671
17	100° 58' 12.63"	4° 23' 7.7"	118.7	81.93100853	1.44877992
18	100° 58' 12.63"	4° 23' 12.875"	119.1	81.93100853	1.453662077
19	100° 58' 6.818"	4° 22' 57.35"	122	81.93100853	1.489057711
20	100° 58' 6.818"	4° 23' 2.525"	104.9	81.93100853	1.280345523
21	100° 58' 6.818"	4° 23' 7.7"	103.1	81.93100853	1.258375819
22	100° 58' 6.818"	4° 23' 12.875"	99.7	81.93100853	1.21687749
23	100° 58' 6.818"	4° 23' 18.05"	132	81.93100853	1.611111621
24	100° 58' 1.006"	4° 22' 47.0"	99.7	81.93100853	1.21687749
25	100° 58' 1.006"	4° 22' 52.175"	124	81.93100853	1.513468493
26	100° 58' 1.006"	4° 22' 57.35"	118.3	81.93100853	1.443897764
27	100° 58' 1.006"	4° 23' 2.525"	115.1	81.93100853	1.404840512
28	100° 58' 1.006"	4° 23' 7.7"	106.8	81.93100853	1.303535766
29	100° 58' 1.006"	4° 23' 12.875"	100.3	81.93100853	1.224200724
30	100° 58' 1.006"	4° 23' 18.05"	123.6	81.93100853	1.508586336
31	100° 57' 55.194"	4° 22' 41.825"	108.6	81.93100853	1.32550547
32	100° 57' 55.194"	4° 22' 52.175"	105.3	81.93100853	1.28522768
33	100° 57' 55.194"	4° 23' 2.525"	103.2	81.93100853	1.259596359
34	100° 57' 55.194"	4° 23' 7.7"	104.5	81.93100853	1.275463367
35	100° 57' 55.194"	4° 23' 12.875"	108.8	81.93100853	1.327946549
36	100° 57' 55.194"	4° 23' 18.05"	116.2	81.93100853	1.418266443
37	100° 57' 55.194"	4° 23' 23.225"	98.29	81.93100853	1.199667888
38	100° 57' 49.382"	4° 22' 41.825"	103.89	81.93100853	1.268018078

39	100° 57' 49.382"	4° 22' 47.0"	112	81.93100853	1.3670038
40	100° 57' 49.382"	4° 22' 52.175"	121.5	81.93100853	1.482955015
41	100° 57' 49.382"	4° 22' 57.35"	120.2	81.93100853	1.467088007
42	100° 57' 49.382"	4° 23' 12.875"	109.7	81.93100853	1.338931401
43	100° 57' 49.382"	4° 23' 18.05"	110.8	81.93100853	1.352357331
44	100° 57' 43.57"	4° 22' 41.825"	123.18	81.93100853	1.503460072
45	100° 57' 43.57"	4° 22' 47.0"	97.4	81.93100853	1.18880509
46	100° 57' 43.57"	4° 22' 52.175"	107.7	81.93100853	1.314520618
47	100° 57' 43.57"	4° 22' 57.35"	116.4	81.93100853	1.420707521
48	100° 57' 43.57"	4° 23' 12.875"	110.2	81.93100853	1.345034096
49	100° 57' 43.57"	4° 23' 18.05"	106.2	81.93100853	1.296212532
50	100° 57' 37.758"	4° 22' 41.825"	118.5	81.93100853	1.446338842
51	100° 57' 37.758"	4° 23' 2.525"	115.18	81.93100853	1.405816944
52	100° 57' 37.758"	4° 23' 7.7"	113.5	81.93100853	1.385311887
53	100° 57' 37.758"	4° 23' 12.875"	89.8	81.93100853	1.096044118
54	100° 57' 31.946"	4° 22' 47.0"	125.86	81.93100853	1.53617052
55	100° 57' 31.946"	4° 22' 52.175"	114.1	81.93100853	1.392635121

Appendix D: Data of moisture content

Sample	Longitude(E)	Latitude(N)	Mass of wet soil + container (m2)	Mass of dry soil + container (m3)	Mass of container (m1)	Moisture Content, W (%)
1	100° 58' 47.502"	4° 22' 52.175"	92.04	85.9	39.44	13.21566939
2	100° 58' 47.502"	4° 22' 57.35"	67.4	60.8	30.4	21.71052632
3	100° 58' 47.502"	4° 23' 2.525"	52.02	49	29.5	15.48717949
4	100° 58' 47.502"	4° 23' 12.875"	60.15	59.12	20.67	2.678803641
5	100° 58' 35.878"	4° 22' 52.175"	61.03	60.56	20.55	1.174706323
6	100° 58' 35.878"	4° 23' 7.7"	58.77	55.97	18.87	7.547169811
7	100° 58' 30.07"	4° 23' 2.525"	63.17	58.24	20.71	13.13615774
8	100° 58' 30.07"	4° 23' 7.7"	58.38	51.95	18.62	19.29192919
9	100° 58' 24.254"	4° 22' 57.35"	1316.12	1251.37	629.69	10.41532621
10	100° 58' 24.254"	4° 23' 7.7"	1316.71	1284.14	775.3	6.400833268
11	100° 58' 24.254"	4° 23' 12.875"	1548.71	1511.54	995.67	7.205303662
12	100° 58' 18.442"	4° 22' 57.35"	1406.05	1329.2	824.26	15.21963006
13	100° 58' 18.442"	4° 23' 7.7"	49.17	44.2	19.2	19.88
14	100° 58' 18.442"	4° 23' 12.875"	49.25	45.6	18.53	13.48356114
15	100° 58' 12.63"	4° 22' 57.35"	50.31	45.4	20.72	19.89465154
16	100° 58' 12.63"	4° 23' 2.525"	48.7	43.1	19.64	23.87041773
17	100° 58' 12.63"	4° 23' 7.7"	49.38	44	18.72	21.28164557
18	100° 58' 12.63"	4° 23' 12.875"	51.92	48.6	20.71	11.90390821
19	100° 58' 6.818"	4° 22' 57.35"	50.17	45.8	19.68	16.73047473
20	100° 58' 6.818"	4° 23' 2.525"	55.6	49.5	22.1	22.26277372
21	100° 58' 6.818"	4° 23' 7.7"	52.01	48.3	19.71	12.97656523
22	100° 58' 6.818"	4° 23' 12.875"	50.6	44.8	19.8	23.2
23	100° 58' 6.818"	4° 23' 18.05"	54.5	51.5	23.5	10.71428571
24	100° 58' 1.006"	4° 22' 47.0"	51.06	46.3	20.61	18.52861035
25	100° 58' 1.006"	4° 22' 52.175"	49.77	45.49	18.94	16.12052731
26	100° 58' 1.006"	4° 22' 57.35"	52.41	49.35	20.66	10.66573719
27	100° 58' 1.006"	4° 23' 2.525"	55.24	51.28	23.21	14.10758817
28	100° 58' 1.006"	4° 23' 7.7"	50.7	46.1	19.8	17.4904943
29	100° 58' 1.006"	4° 23' 12.875"	50.8	44.4	20.6	26.8907563
30	100° 58' 1.006"	4° 23' 18.05"	50.5	47.2	18.8	11.61971831
31	100° 57' 55.194"	4° 22' 41.825"	51.07	46.3	19.42	17.74553571
32	100° 57' 55.194"	4° 22' 52.175"	51.05	47.02	20.66	15.28831563
33	100° 57' 55.194"	4° 23' 2.525"	52.73	47.93	19.32	16.77735058
34	100° 57' 55.194"	4° 23' 7.7"	50.4	45	19.1	20.84942085
35	100° 57' 55.194"	4° 23' 12.875"	49.88	44.8	18.77	19.51594314
36	100° 57' 55.194"	4° 23' 18.05"	52.04	47.7	19.35	15.30864198

37	100° 57' 55.194"	4° 23' 23.225"	1622.57	1526.24	1004.6	18.46675868
38	100° 57' 49.382"	4° 22' 41.825"	51.77	45.9	20.74	23.33068362
39	100° 57' 49.382"	4° 22' 47.0"	55.7	50.8	22.5	17.31448763
40	100° 57' 49.382"	4° 22' 52.175"	50.14	46.28	20.04	14.71036585
41	100° 57' 49.382"	4° 22' 57.35"	50.02	45.24	19.53	18.59198755
42	100° 57' 49.382"	4° 23' 12.875"	50.89	47.92	20.05	10.65662002
43	100° 57' 49.382"	4° 23' 18.05"	49.8	45.74	19.52	15.48436308
44	100° 57' 43.57"	4° 22' 41.825"	48.5	45.3	18.84	12.09372638
45	100° 57' 43.57"	4° 22' 47.0"	51.5	44	20.7	32.1888412
46	100° 57' 43.57"	4° 22' 52.175"	53.9	46.9	21.22	27.25856698
47	100° 57' 43.57"	4° 22' 57.35"	49.3	44.7	18.8	17.76061776
48	100° 57' 43.57"	4° 23' 12.875"	51.23	48.7	19.84	8.766458766
49	100° 57' 43.57"	4° 23' 18.05"	50.9	46.7	19.7	15.55555556
50	100° 57' 37.758"	4° 22' 41.825"	50.34	45.1	19.77	20.68693249
51	100° 57' 37.758"	4° 23' 2.525"	51.81	46.1	21.31	23.03348124
52	100° 57' 37.758"	4° 23' 7.7"	48.23	43.5	18.63	19.01889827
53	100° 57' 37.758"	4° 23' 12.875"	50.4	43.5	19.7	28.99159664
54	100° 57' 31.946"	4° 22' 47.0"	53.96	50.5	23.22	12.68328446
55	100° 57' 31.946"	4° 22' 52.175"	51	45.6	20.67	21.66064982

Appendix E: Data of organic content

Sample	Longitude(E)	Latitude(N)	Organic content (%)
1	100° 58' 47.502"	4° 22' 52.175"	6.887645286
2	100° 58' 47.502"	4° 22' 57.35"	22.03947368
3	100° 58' 47.502"	4° 23' 2.525"	13.33333333
4	100° 58' 47.502"	4° 23' 12.875"	6.033810143
5	100° 58' 35.878"	4° 22' 52.175"	7.328447702
6	100° 58' 35.878"	4° 23' 7.7"	12.1182266
7	100° 58' 30.07"	4° 23' 2.525"	6.715916723
8	100° 58' 30.07"	4° 23' 7.7"	12.65700483
9	100° 58' 24.254"	4° 22' 57.35"	17.43572841
10	100° 58' 24.254"	4° 23' 7.7"	9.587217044
11	100° 58' 24.254"	4° 23' 12.875"	4.644268775
12	100° 58' 18.442"	4° 22' 57.35"	10.59755695
13	100° 58' 18.442"	4° 23' 7.7"	6.812894649
14	100° 58' 18.442"	4° 23' 12.875"	5.280528053
15	100° 58' 12.63"	4° 22' 57.35"	2.287581699
16	100° 58' 12.63"	4° 23' 2.525"	7.836990596
17	100° 58' 12.63"	4° 23' 7.7"	3.666666667
18	100° 58' 12.63"	4° 23' 12.875"	13.1147541
19	100° 58' 6.818"	4° 22' 57.35"	8.863138115
20	100° 58' 6.818"	4° 23' 2.525"	4.332810047
21	100° 58' 6.818"	4° 23' 7.7"	20.77922078
22	100° 58' 6.818"	4° 23' 12.875"	19.52489424
23	100° 58' 6.818"	4° 23' 18.05"	21.66666667
24	100° 58' 1.006"	4° 22' 47.0"	11.18421053
25	100° 58' 1.006"	4° 22' 52.175"	2.317880795
26	100° 58' 1.006"	4° 22' 57.35"	15.40489642
27	100° 58' 1.006"	4° 23' 2.525"	19.34471941
28	100° 58' 1.006"	4° 23' 7.7"	22.0163876
29	100° 58' 1.006"	4° 23' 12.875"	19.86970684
30	100° 58' 1.006"	4° 23' 18.05"	25.16556291
31	100° 57' 55.194"	4° 22' 41.825"	14.66666667
32	100° 57' 55.194"	4° 22' 52.175"	2.280130293
33	100° 57' 55.194"	4° 23' 2.525"	10.31866464
34	100° 57' 55.194"	4° 23' 7.7"	17.58126529
35	100° 57' 55.194"	4° 23' 12.875"	21.52317881

36	100° 57' 55.194"	4° 23' 18.05"	15.75105647
37	100° 57' 55.194"	4° 23' 23.225"	18.69488536
38	100° 57' 49.382"	4° 22' 41.825"	20.82931533
39	100° 57' 49.382"	4° 22' 47.0"	2.990033223
40	100° 57' 49.382"	4° 22' 52.175"	17.46987952
41	100° 57' 49.382"	4° 22' 57.35"	22.35872236
42	100° 57' 49.382"	4° 23' 12.875"	15.00622665
43	100° 57' 49.382"	4° 23' 18.05"	14.33447099
44	100° 57' 43.57"	4° 22' 41.825"	12.25109686
45	100° 57' 43.57"	4° 22' 47.0"	1.973684211
46	100° 57' 43.57"	4° 22' 52.175"	27.54098361
47	100° 57' 43.57"	4° 22' 57.35"	21.02803738
48	100° 57' 43.57"	4° 23' 12.875"	17.04897706
49	100° 57' 43.57"	4° 23' 18.05"	10.3950104
50	100° 57' 37.758"	4° 22' 41.825"	15.70512821
51	100° 57' 37.758"	4° 23' 2.525"	2.295081967
52	100° 57' 37.758"	4° 23' 7.7"	3.606557377
53	100° 57' 37.758"	4° 23' 12.875"	2.51572327
54	100° 57' 31.946"	4° 22' 47.0"	27.36156352
55	100° 57' 31.946"	4° 22' 52.175"	3.270111184

Appendix F: Data of particle size distribution

Sample	Longitude(E)	Latitude(N)	Sieve										Soil + Sieve									
			3.35 mm	2 mm	1.18 mm	600 µm	425 µm	300 µm	212 µm	150 µm	63 µm	Passing 63 µm	3.35 mm	2 mm	1.18 mm	600 µm	425 µm	300 µm	212 µm	150 µm	63 µm	Passing 63 µm
1	100° 58' 47.502"	4° 22' 52.175"	484.97	381.49	434.95	339.71	366.62	336.88	270.06	307.56	245.5	245.53	514.15	401.97	463.7	367.57	394.33	326.63	366.17	307.6	380.39	262.81
2	100° 58' 47.502"	4° 22' 57.35"	484.44	381.44	435.16	339.87	367.72	366.38	340.38	266.92	326.96	245.53	508.75	417.86	454.24	409.27	405.31	329.8	384.12	305.63	368.95	264.27
3	100° 58' 47.502"	4° 23' 2.525"	484.39	381.47	435.23	339.28	366.02	366.58	340.53	270.48	326.93	245.44	507.97	414.17	480.04	406.23	405.25	330.77	365.63	306.89	380.33	265.85
4	100° 58' 47.502"	4° 23' 12.875"	484.57	380.99	425.91	406.27	369.67	356.03	339.67	269.22	326.43	245.47	494.2	494.2	492.83	476.21	469.35	400.21	405.58	279.01	338.91	247.04
5	100° 58' 35.878"	4° 22' 52.175"	484.59	380.95	425.88	404.87	369.4	345.86	338.5	267.43	323.89	245.43	518.7	502.75	503.75	457.57	448.38	381.14	421.86	293.23	344.98	248.6
6	100° 58' 35.878"	4° 23' 7.7"	484.43	380.49	426.08	400.95	368.64	350.87	338.58	268.79	325.6	245.48	507.4	425.46	474.46	474.39	427.6	432.4	426.53	322.82	361.86	265.46
7	100° 58' 30.07"	4° 23' 2.525"	484.51	384.29	428.23	339.49	372.26	359.14	342.14	333.88	327.29	245.52	510.31	432.86	487.55	411.93	421.82	354.26	367.84	362.49	396.52	279.5
8	100° 58' 30.07"	4° 23' 7.7"	484.25	384.2	426.8	400.04	369.89	354.87	341.58	332.76	326.77	244.97	511.38	566.46	502.87	417.21	418.11	368.01	395.24	348.92	349.5	247.93
9	100° 58' 24.254"	4° 22' 57.35"	484.29	382.22	434.97	408.27	367.2	367.7	340.9	270.64	327.11	245.48	515.21	439.12	499.82	482.9	416.18	429.54	392.93	309.08	371.33	263.02
10	100° 58' 24.254"	4° 23' 7.7"	484.22	382.3	435.28	408.05	368.34	340.8	259.62	269.92	326.79	234.46	530.06	457.33	492.93	472.36	407.93	423.15	395.54	313.58	373.32	257.75
11	100° 58' 24.254"	4° 23' 12.875"	484.43	382.09	435.06	339.62	372.18	367.71	345.47	270.56	326.48	245.83	486.13	397.27	454.44	365.66	410.43	432.07	426.95	353.75	456.65	308.51
12	100° 58' 18.442"	4° 22' 57.35"	484.8	382.45	427	339.59	372.11	369.42	341.26	334.01	327.03	245.51	528.21	455.34	488.34	424.46	410.31	421.48	394.22	377.57	381.08	270.96
13	100° 58' 18.442"	4° 23' 7.7"	482.3	379.4	424.2	338.1	366	366.6	338.8	310.1	325.7	244.3	499.4	408.7	469.5	405.4	405.7	427.2	404.9	370.2	369.8	271.4
14	100° 58' 18.442"	4° 23' 12.875"	482.3	379.5	424	338.1	365.7	366.1	338.4	309.9	325.6	244.4	520.7	439.3	497.1	428.7	414	423.8	387	345.5	364	260.1
15	100° 58' 12.63"	4° 22' 57.35"	482.3	379.5	424.1	338.1	366.2	366.4	338.8	309.8	325.7	244.3	501.3	410.6	474.1	412.7	407	417.7	390.8	359.5	421.6	267.7
16	100° 58' 12.63"	4° 23' 2.525"	484.1	381.04	434.91	305.04	369.18	355.87	328.69	269.27	326.95	245.37	499.21	410.42	484.73	388.71	420.07	420.94	432.79	320.16	391.75	273.14
17	100° 58' 12.63"	4° 23' 7.7"	482.2	378.2	422.8	338.1	365.4	366.1	338.5	309.5	324.7	244.4	518.7	414.1	470.7	422.9	406.7	428.4	422.2	381.6	398.8	277.5
18	100° 58' 12.63"	4° 23' 12.875"	484.1	381.7	434.8	339.4	371.8	367.8	340.3	269.5	326.5	245.3	524.04	407.2	479.2	427.8	417.1	430.4	427.9	328.5	397.8	273.1
19	100° 58' 6.818"	4° 22' 57.35"	484.2	383.3	435.2	408.1	368.7	368.3	340.8	269.9	326.7	245.5	500.2	403.5	458.7	415.8	409.8	430.5	420.6	380.2	408.7	267.8
20	100° 58' 6.818"	4° 23' 2.525"	484.2	380.8	434.9	305	369.3	371.1	341.1	269	326.4	245.3	526.8	409.6	481.4	379.7	411.5	430.4	401.1	615	392	280.4
21	100° 58' 6.818"	4° 23' 7.7"	484.4	379.3	424.1	338.1	366.8	366.1	338.4	308.1	326.7	244.4	521.1	409.9	483.5	405.8	420.4	411.7	418.4	330.3	398.4	269.1
22	100° 58' 6.818"	4° 23' 12.875"	482.8	379.6	433.4	304	367.9	369.7	340	268.1	325.5	245.6	511.7	412.7	481.5	372	410	432.9	403.2	318	414.3	279.9
23	100° 58' 6.818"	4° 23' 18.05"	482.3	379.5	424.1	338.4	366.2	367	339.4	310.3	325.7	244.4	524.7	410.2	481.7	383.8	397.1	415.8	401.5	373.8	432.9	266.8
24	100° 58' 1.006"	4° 22' 47.0"	484.3	382	434.8	339.5	372.1	368.6	340.6	269.8	326.5	245.4	495.7	420.9	471.5	422.8	369.8	433.3	411.2	307.5	412.5	267.2
25	100° 58' 1.006"	4° 22' 52.175"	484.5	382.6	424.1	305.4	369.3	371.2	340.1	269	326.1	245.4	507.4	410.1	471.5	379.1	417.2	425.8	412.8	345.1	421.1	266.4
26	100° 58' 1.006"	4° 22' 57.35"	484.4	382.7	424	305.4	369.5	371.1	369.8	269.4	326.3	245	502.3	402.5	482.1	383.4	408.3	417.6	419.4	331.8	428.3	269.8
27	100° 58' 1.006"	4° 23' 2.525"	484.4	382.4	424	306.7	369.3	371.4	370.2	269.2	326.1	244.7	498.7	415.2	463.7	389.3	412.4	431.4	408.2	317.8	418.7	260.8
28	100° 58' 1.006"	4° 23' 7.7"	482.5	379.8	424.3	338.1	365.9	366.4	338.5	309.7	325.7	244.5	488.4	402.5	463.6	401.1	407.8	433.8	414.7	377	411	265.5
29	100° 58' 1.006"	4° 23' 12.875"	482.4	380	424.2	338.3	366.9	367.4	340	310.8	325.7	244.3	500.7	430.5	485.7	418.5	408.8	422.6	394.5	358.3	392.4	272.8
30	100° 58' 1.006"	4° 23' 18.05"	482.5	379.7	424.3	338.2	365.9	367.8	338.5	309.8	325.7	244.3	505.7	417.8	481.5	417.3	412.7	432.9	389.3	362	385.4	269.9
31	100° 57' 55.194"	4° 22' 41.825"	424.4	379.5	424	338.3	366	366.5	338.8	310	325.9	244.5	493.4	397.5	447.1	369.8	411	462.6	433.4	367.2	409.4	275.8
32	100° 57' 55.194"	4° 22' 52.175"	482.5	379.6	424	338.2	366.3	366.5	338.7	310.2	325.5	244.4	502.4	399.8	442.1	371.4	407.4	463.7	426.8	398.1	405.4	277.3
33	100° 57' 55.194"	4° 23' 2.525"	482.4	379.6	424.1	338.3	366.2	366.3	338.8	309.4	325.1	244.4	499.1	397.8	451.4	371.2	404.5	465.2	431.9	383.7	405.4	277.1
34	100° 57' 55.194"	4° 23' 7.7"	484.1	380.8	434.8	305	369.1	371	341	270.8	326.3	245.3	515	413	485.1	382.8	418.1	430.6	388	314.8	388.1	274.4
35	100° 57' 55.194"	4° 23' 12.875"	484	380.7	434.8	305	369.1	371	341	269.2	326.3	245.3	508.4	420.2	485.4	395.7	416.2	429.5	388.4	315.8	383.6	273.6
36	100° 57' 55.194"	4° 23' 18.05"	484	380.9	434.8	305.1	369.1	371	341	269	326.3	128.3	507.8	427.5	498.8	393.7	415.3	429.8	388	315.6	382.4	266.7
37	100° 57' 55.194"	4° 23' 23.225"	484.53	382.66	426.81	339.78	372.41	369.34	341.33	334.34	327.03	245.46	514.87	431.8	493.97	412.91	415.41	425.61	421.83	388.41	387.43	269.55
38	100° 57' 49.382"	4° 22' 41.825"	484.17	382.88	434.91	305.25	369.21	355.86	339.65	269.23	326.47	245.38	542.54	443.2	503.25	375.02	389.1	287.38	387.43	301.25	442	264.58
39	100° 57' 49.382"	4° 22' 47.0"	482.6	379.5	424.5	339.2	367.1	369.4	340.8	310.8	325.2	244.5	485.3	400.5	453.6	383.2	399.5	442.2	427.2	384.6	431.9	344.3
40	100° 57' 49.382"	4° 22' 52.175"	482.4	380	424.2	338.3	366.9	367.4	340	310.8	325.7	244.3	504.9	417.5	488.3	387.4	421.5	420.9	403.7	352.6	385.8	273.8
41	100° 57' 49.382"	4° 22' 57.35"	482.3	379.4	424.2	338.1	366	366.6	338.8	310.1	325.7	244.4	523.6	412.8	487.2	382.6	424.5	431.8	398.1	363.5	372.4	268.1
42	100° 57' 49.382"	4° 23' 12.875"	482.3	379.5	424.1	338.4	366.2	367	339.4	310.3	325.7	244.4	513.1	413.5	480.9	374.2	412.8	433.3	405	320.4	418.2	280.1
43	100° 57' 49.382"	4° 23' 18.05"	482.6	379.5	424.5	339.2	367.1	369.4	340.8	310.8	325.2	244.5	512.5	413.8	481.5	383.7	408.6	415.8	389.2	322.3	432	288.1
44	100° 57' 43.57"	4° 22' 41.825"	484.25	381.1	435.05	292.6	369.31	355.9	339.67	269.24	326.53	245.38	529.49	414.38	477.59	365.67	408.37	412.79	401.53	324.9	434.82	274.88
45	100° 57' 43.57"	4° 22' 47.0"	484	380.7	434.9	305	369.2	371	341	269	326.4	245.3	523.1	414.5	482	388.6	411.5	423.5	397.6	312.1	388.2	285.1
46	100° 57' 43.57"	4° 22' 52.175"	484.3	380.9	434.8	305	369.4	371.2	341.1	269.3	326.4	245.3	527.3	403.2	486.5	389.8	415.4	422.8	385	319.1	408.9	282.4
47	100° 57' 43.57"	4° 22' 57.35"	484	380.9	434.8	305	369	371	341.1	269	326.3	245.3	511.1	405.4	484.5	382.8	412	422.3	390.6	315.8	415.7	283.9
48	100° 57' 43.57"	4° 23' 12.875"	484.3	379.1	432.8	338.7	367.3	288.4	340.5	269.4	325.1	244.4	513.5	407.5	477.2	406.1	421.7	420.4	408.1	328.2	393.2	272.4
49	100° 57' 43.57"	4° 23' 18.05"	484.1	381.2	435.1	305.6	369.1	371	341	269	326.2	245.4	538.6	412.8	479.4	385.2	402.8	417.4	395.8	322.1	430.4	289.4
50	100° 57' 37.758"	4° 22' 41.825"	484.1	381.1	434.8	339.4	371.4	367.7	342	269.2	326.8	245.3	553.4	408.8	473.7	413.1	413.2	437.2	388	320.8	408.3	259.1
51	100° 57' 37.758"	4° 23' 2.525"	484.18	382.92	434.87	305.09	369.32	355.89	342	269.22	326.52	245.33	507.5	424.88	475.91	382.65	386.3	388.47	388.83	318.72	412.18	280.88
52	100° 57' 37.758"	4° 23' 7.7"	482.2	379.6	424.1	338.3	365.9	366.2	338.9	309.9	325.7	244.5	504	405.1	482.9	420	388.3	412.8	389	355.2	385	279.8
53	100° 57' 37.758"	4° 23' 12.875"	484.2	380.9	434.7	305	369	371	341	269	326.3	245.3	488.5	388.3	479.6	411.1	429.8	442.4	431.3	314	391	281.6
54	100° 57' 31.946"	4° 22' 47.0"	484.28	382.88	434.88	308.03	369.37	325.19	289.34	330.73	328.88	245.39	518.04	422.57	484.49	393.8	403.7	328.3	359.39	330.83	379.79	288.28
55	100° 57' 31.946"	4° 22' 52.175"	484.2	379.5	424	338.2	365.7	366.2	338.8	309.7	325.8	244.4	529	440.8	489.8	408.8	398.8	432.4	372.1	338.7	424.9	273.9

Sample	Longitude(E)	Latitude(N)	Mass Retained (g)										Percentage Retained,%									
			3.35 mm	2 mm	1.18 mm	600 µm	425 µm	300 µm	212 µm	150 µm	63 µm	Passing 63µm	3.35 mm	2 mm	1.18 mm	600 µm	425 µm	300 µm	212 µm	150 µm	63 µm	Passing 63 µm
1	100° 58' 47.502"	4° 22' 52.175"	29.18	20.48	28.75	47.86	107.71	57.45	116.11	0.04	134.89	47.28	4.9478659	3.4726558	4.8748947	8.1153033	18.263367	9.7414418	19.6888	0.0067783	22.87724	8.01656563037
2	100° 58' 47.502"	4° 22' 57.35"	24.31	36.42	49.08	69.4	37.59	118.93	43.74	38.91	41.99	18.74	6.0567596	9.0739022	12.228112	17.290378	9.3654423	29.631101	10.897798	9.6942297	10.461657	4.66902365445
3	100° 58' 47.502"	4° 23' 2.525"	23.58	32.7	44.81	66.95	37.23	118.67	45.1	36.41	53.4	20.41	5.833168	8.0892254	11.0865	16.561164	9.2098675	29.356532	11.159574	9.0270295	13.203897	5.04869823603
4	100° 58' 47.502"	4° 23' 12.875"	9.83	113.21	66.92	69.94	119.68	133.32	65.91	9.79	12.48	1.57	1.5984473	18.79918	11.107798	11.609026	19.865555	22.129564	11.840033	1.6256031	2.0721541	0.26068025254
5	100° 58' 35.878"	4° 22' 52.175"	34.11	121.79	77.87	52.7	78.98	102.52	83.36	15.8	21.09	3.17	6.8183118	24.344485	15.565569	10.534311	15.787447	20.492293	16.6653	3.1582565	4.2157724	0.633635578025
6	100° 58' 35.878"	4° 23' 7.7"	22.97	44.97	48.38	73.43	58.96	76.73	87.97	54.03	36.26	19.98	4.5095626	8.8873852	9.5612665	14.511185	11.652117	15.164033	17.388528	10.677797	7.1665308	3.94886188501
7	100° 58' 30.07"	4° 23' 2.525"	25.8	48.57	59.32	72.44	49.56	62.68	45.7	28.81	69.23	33.98	4.7438898	8.9306507	10.907722	13.31956	9.1126539	11.525502	8.4028898	5.2825545	12.729508	6.24776314853
8	100° 58' 30.07"	4° 23' 7.7"	27.13	172.28	76.07	17.17	48.22	63.24	53.66	16.16	22.73	2.56	5.1330008	32.591657	14.392248	3.2485572	9.1232245	11.965504	10.15205	3.0574479	4.3005528	0.48435531124
9	100° 58' 24.254"	4° 22' 57.35"	30.92	56.9	64.85	84.63	48.98	48.48	52.03	37.42	44.22	17.54	6.1817775	11.37598	12.966533	16.918931	9.7924475	9.6925511	10.402228	7.4813037	8.8408817	3.50657375574
10	100° 58' 24.254"	4° 23' 7.7"	45.84	75.03	57.87	64.31	39.59	67.13	125.92	43.66	46.53	33.29	7.8653108	12.52865	9.6281165	10.736776	6.603968	11.207757	21.022278	7.289918	7.7660336	5.55778746381
11	100° 58' 24.254"	4° 23' 12.875"	1.7	15.18	19.38	28.04	38.25	42.72	83.48	83.19	129.17	142.58	0.0090098	0.0812242	0.103572	0.1393663	0.20471	0.2286503	0.4467775	0.4452223	0.6913033	0.76365071772
12	100° 58' 18.442"	4° 22' 57.35"	43.61	72.89	61.34	64.87	38.2	40.89	52.96	43.56	54.05	25.45	8.5860365	14.354454	12.080033	12.775522	7.5229443	8.05527	10.429771	8.5786518	10.644437	5.01220130277
13	100° 58' 18.442"	4° 23' 7.7"	17.1	29.3	45.3	67.3	39.7	39.1	66.1	60.1	44.1	27	3.3921184	5.8123539	8.9863112	13.350353	7.8754422	7.7583398	13.112248	11.922224	8.7482264	5.35592801143
14	100° 58' 18.442"	4° 23' 12.875"	38.4	59.8	73.1	90.6	48.3	47.9	48.6	35.6	38.4	15.7	7.5799445	11.804118	14.429053	17.885093	9.5341459	9.4555191	9.5935398	7.027724	7.5799445	3.09909191986
15	100° 58' 12.63"	4° 22' 57.35"	19	31.1	50	74.6	40.8	40.6	52	49.7	95.9	43.4	3.7308111	6.1064221	9.8177398	14.647198	8.0113995	7.9717726	10.210209	9.7564482	18.829977	8.52115203989
16	100° 58' 12.63"	4° 23' 2.525"	15.11	29.38	49.82	83.67	50.89	64.2	74.1	50.89	64.8	27.77	3.0194033	5.8709951	9.9554438	16.719952	10.169225	12.828997	14.807727	10.169225	12.948885	5.54932277864
17	100° 58' 12.63"	4° 23' 7.7"	36.5	35.9	47.9	64.8	41.3	40.6	63.7	52.1	74.1	33.1	7.1777974	7.059998	9.4196652	12.743306	8.1216327	7.9842657	12.527704	10.245582	14.572227	6.5093412
18	100° 58' 12.63"	4° 23' 12.875"	39.94	25.5	43.4	68.4	45.3	49.3	67.6	57	71.3	27.8	7.8655301	5.0221652	8.5466572	13.468457	8.9205635	9.7085547	13.312333	11.224489	14.040398	5.47459952598
19	100° 58' 6.818"	4° 22' 57.35"	16	20.2	23.5	7.7	41.1	41.5	79.8	110.5	82	42.3	3.4445564	4.3487582	5.0592033	1.6577598	8.8482224	8.9343098	17.179778	23.745598	17.653039	9.10659952
20	100° 58' 6.818"	4° 23' 2.525"	42.6	28.8	46.5	74.7	42.2	40.4	60	346	65.6	34.1	8.5165593	5.7578597	9.2962281	14.934403	8.4366525	8.0767769	11.99952	69.172033	13.114475	6.81727363911
21	100° 58' 6.818"	4° 23' 7.7"	36.7	30.6	59.4	67.7	53.6	54.3	80	22.2	71.7	44.7	7.0454498	5.8744445	11.403034	12.996774	10.288998	10.424427	15.358053	4.2618564	13.764454	8.58113011583
22	100° 58' 6.818"	4° 23' 12.875"	28.9	33.1	48.1	68	42.1	40.3	63.2	49.9	88.8	33.3	5.6912217	6.5185314	9.4722033	13.39111	8.2909995	7.9361195	12.445584	9.8267733	17.48872	6.55775998882
23	100° 58' 6.818"	4° 23' 18.05"	22.4	30.7	37.6	45.4	30.9	30.1	62.1	63.5	107.2	52.4	4.4710358	6.1277445	7.504489	9.0618776	6.1679665	6.0079864	12.395521	12.674465	21.397721	10.4559038184
24	100° 58' 1.006"	4° 22' 47.0"	11.4	18.9	38.7	63.3	-2.3	1.2	70.6	37.7	86	41.8	2.2745541	3.770965	7.7223428	12.629859	-0.45899	0.2394425	14.086619	7.5221947	17.159882	8.34009442338
25	100° 58' 1.006"	4° 22' 52.175"	22.9	27.5	47.4	72.7	47.9	46	72.7	76.1	95	51	4.0965136	4.91774	8.4793595	13.005372	8.5688438	8.2290337	13.005372	13.613673	16.994598	9.12331718574
26	100° 58' 1.006"	4° 22' 57.35"	17.9	19.8	58.1	77	38.8	37.2	49.6	62.4	102	44.8	3.5295599	3.9037739	11.445932	15.185442	7.6438814	7.3346635	9.7714474	12.293014	20.09466	8.83358477124
27	100° 58' 1.006"	4° 23' 2.525"	14.3	32.8	39.7	82.6	43.1	41	38	48.6	92.6	46.1	2.9898933	6.6924459	8.2915562	17.251445	8.9201671	8.5933074	7.9266538	10.153363	19.346332	9.62823727
28	100° 58' 1.006"	4° 23' 7.7"	5.9	22.7	39.3	63	41.9	41.4	76.2	67.3	85.3	41	1.1573317	4.4527227	7.7089605	12.357779	8.2188439	8.1209332	14.947734	13.201126	16.732205	8.04223858557
29	100° 58' 1.006"	4° 23' 12.875"	18.3	50.5	61.5	78.2	42.9	42.4	54.5	47.5	67.7	28.5	3.6033115	10.022581	12.209885	15.525111	8.5169974	8.4177739	10.819993	9.4302218	13.442354	5.65861298039
30	100° 58' 1.006"	4° 23' 18.05"	23.2	38.1	57.2	79.1	46.8	44.9	60.8	52.2	59.7	22.6	4.5977701	7.5505306	11.335571	15.675778	9.2748573	8.8981137	12.049915	10.344483	11.831115	4.47878958385
31	100° 57' 55.194"	4° 22' 41.825"	69	18	23.1	31.5	45	44.5	94.6	77.2	80.5	31.3	13.555599	3.5260346	4.528031	6.1888826	8.8408894	8.7428033	18.585546	15.159999	15.815022	6.14880123577
32	100° 57' 55.194"	4° 22' 52.175"	19.9	20.2	18.1	33.2	41.1	40.9	88.1	87.9	79.9	32.9	4.3035465	4.3704422	3.9180354	7.1830280	8.8922254	8.8469963	19.281121	19.217776	17.288859	7.11811328879
33	100° 57' 55.194"	4° 23' 2.525"	16.7	18.2	27.3	32.9	38.3	38.2	93.1	74.3	81.3	32.7	3.6885534	4.017788	6.028849	7.2829583	8.4547748	8.4328771	20.351188	16.421177	17.947722	7.21885430348
34	100° 57' 55.194"	4° 23' 7.7"	30.9	32.2	50.3	87.8	49	47.1	57	44	59.8	28.1	6.1431441	6.431158	10	17.405527	9.7415581	9.3838117	11.353221	8.7457315	11.888857	5.59554811113
35	100° 57' 55.194"	4° 23' 12.875"	24.4	39.5	50.6	90.7	47.1	45.2	57.4	46.6	57.3	24.1	5.0528808	8.1797747	10.478898	18.792238	9.7928772	9.3882118	11.888852	9.6592281	11.885581	4.38608813
36	100° 57' 55.194"	4° 23' 18.05"	23.6	46.6	63.8	88.6	46.2	44.3	57	46.6	56.1	140.4	4.8522987	9.1877597	12.579888	17.488845	9.1388833	8.7342227	11.238117	9.1877597	11.088373	27.6811388831
37	100° 57' 55.194"	4° 23' 23.225"	30.34	48.94	67.16	73.15	43	46.07	60.6	52.07	60.4	23.39	5.9022298	9.5223327	13.087742	14.23329	8.3888573	8.8838807	11.791133	10.131134	11.752112	4.49228548328
38	100° 57' 49.382"	4° 22' 41.825"	58.37	62.32	65.34	69.77	29.89	43.25	27.78	32.02	115.53	19.2	11.483229	12.171188	12.781172	13.828585	5.8377881	8.4467288	5.4225781	6.2532808	22.386445	3.79
39	100° 57' 49.382"	4° 22' 47.0"	12.7	21	29.1	41	32.4	30.1	86.4	73.8	106.7	99.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.204429	[illegible]
40	100° 57' 49.382"	4° 22' 52.175"	22.5	37.5	64.1	49.1	54.6	54.1	63.7	41.8	73.1	28.2	[illegible]	[illegible]	13.252232	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
41	100° 57' 49.382"	4° 22' 57.35"	41.3	33.4	60	54.5	58.5	57.9	59.3	53.4	46.7	21.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	100° 57' 49.382"	4° 23' 12.875"	30.8	34	58.8	35.8	46.6	45.8	66.6	10.1	90.5	38.7	[illegible]	7.327712	12.574472	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	100° 57' 49.382"	4° 23' 18.05"	27.9	34.3	57	24.5	41.5	39.2	58.4	11.7	106.8	43.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
44	100° 57' 43.57"	4° 22' 41.825"	45.24	33.28	42.5	73.07	39.38	52.47	61.86	56.66	79.29	29.52	[illegible]	[illegible]	[illegible]	14.522349	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45	100° 57' 43.57"	4° 22' 47.0"	19.1	33.8	57.1	84.6	42.3	40.5	56.6	43.1	38.8	18.8	[illegible]	[illegible]	11.37448	[illegible]	[illegible]	[illegible]	11.27148	[illegible]	[illegible]	[illegible]
46	100° 57' 43.57"	4° 22' 52.175"	23	22.3	51.7	84.8	44	42.2	51.9	49.8	82.5	46.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
47	100° 57' 43.57"	4° 22' 57.35"	27.1	24.5	49.7	87.6	43	41	45.5	46.8	88.4	37.6	[illegible]	[illegible]	[illegible]	17.34811	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
48	100° 57' 43.57"	4° 23' 12.875"	29.2	28.4	44.4	72.4	53.8	136.3	67.6	58.8	66.1	28	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
49	100° 57' 43.57"	4° 23' 18.05"	25.5	31.6	44.3	58.6	33.8	31.9	54.8	53.1	104.2	43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	100° 57' 37.758"	4° 22' 41.825"	69.3	19.5	38.9	73.7	41.8	45.5	58	51.6	73.7	23.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51	100° 57' 37.758"	4° 23' 2.525"	83.34	44.54	42.54	47.38	27.58	40.91	48.83	47.5	83.67	45.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
52	100° 57' 37.758"	4° 23' 7.7"	51.8	55.5	59.8	64.7	32.6	32.3	46.4	43.3	69.3	38.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
53	100° 57' 37.758"	4° 23' 12.875"	4.3	14.4	41.9	106.1	60.8	58.9	60.3	45	64.7	38.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
54	100° 57' 31.946"	4° 22' 47.0"	33.78	38.58	58.51	4.77	54.33	88.51	130.38	0.1	50.1	20.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55	100° 57' 31.946"	4° 22' 52.175"	54.8	61.3	65.8	73.4	30.9	30.4	33.9	29	88	28.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Appendix G: Data of specific gravity

Longitude(E)	Latitude(N)	Mass of jar+gas jar+plate (m1)	Mass of jar+gas jar+plate+soil (m2)	Mass of jar+gas jar+plate+soil+water (m3)	Mass of jar+gas jar+plate+water (m4)	Particle density (m2-m1) / (m4-m1)-(m3-m2)
100° 58' 47.502"	4° 22' 52.175"	539.41	930.62	1621.41	1542.43	1.252954553
100° 58' 47.502"	4° 22' 57.35"	541.21	912.78	1595.65	1531.2	1.209852826
100° 58' 47.502"	4° 23' 2.525"	538.95	877.42	1075.4	1507.7	0.439132296
100° 58' 47.502"	4° 23' 12.875"	543.93	820.07	1640.66	1548.66	1.499619854
100° 58' 35.878"	4° 22' 52.175"	541.17	904.6	1729.42	1554.38	1.929136366
100° 58' 35.878"	4° 23' 7.7"	540.8	973.09	1696.91	1547.17	1.529959299
100° 58' 30.07"	4° 23' 2.525"	539.66	860.76	1677.19	1554.97	1.614541432
100° 58' 30.07"	4° 23' 7.7"	541.16	764.39	1570.29	1552.54	1.086383103
100° 58' 24.254"	4° 22' 57.35"	544.96	945.46	1801.67	1542.6	2.831789578
100° 58' 24.254"	4° 23' 7.7"	540.29	979.26	1775.01	1565.35	1.914308142
100° 58' 24.254"	4° 23' 12.875"	542.25	1028.28	1841.32	1524.74	2.868279729
100° 58' 18.442"	4° 22' 57.35"	540.85	932.96	1777.73	1513.57	3.064556467
100° 58' 18.442"	4° 23' 7.7"	584.9	1034.7	1861.6	1549.5	3.266521423
100° 58' 18.442"	4° 23' 12.875"	479.6	883.5	1750.5	1517.4	2.364754098
100° 58' 12.63"	4° 22' 57.35"	533	981.3	1801.6	1551.8	2.258438287
100° 58' 12.63"	4° 23' 2.525"	540.6	984.23	1809.59	1560.8	2.276893862
100° 58' 12.63"	4° 23' 7.7"	538.5	966.2	1799.1	1552.8	2.357772878
100° 58' 12.63"	4° 23' 12.875"	533.86	978.01	1811.07	1559.61	2.304997665
100° 58' 6.818"	4° 22' 57.35"	539.8	984.25	1786.95	1551.4	2.127573001
100° 58' 6.818"	4° 23' 2.525"	532	955.8	1793.81	1558.86	2.244109081
100° 58' 6.818"	4° 23' 7.7"	540.4	999.7	1775.9	1560.2	1.88546798
100° 58' 6.818"	4° 23' 12.875"	534.4	975.6	1804.51	1557.56	2.271299871
100° 58' 6.818"	4° 23' 18.05"	481	926.2	1791.37	1525.22	2.486456297
100° 58' 1.006"	4° 22' 47.0"	534.67	996.17	1828.31	1558.13	2.412189003
100° 58' 1.006"	4° 22' 52.175"	541	986.3	1831.6	1555.8	2.627138643
100° 58' 1.006"	4° 22' 57.35"	538.7	1008.7	1789.3	1560.4	1.94939859
100° 58' 1.006"	4° 23' 2.525"	542.4	979.5	1777.8	1558.3	2.008731618
100° 58' 1.006"	4° 23' 7.7"	535.2	1012.1	1829.96	1558.17	2.325093852
100° 58' 1.006"	4° 23' 12.875"	531.5	970.5	1801.63	1559.79	2.226617975
100° 58' 1.006"	4° 23' 18.05"	536.1	974.4	1831.95	1571.3	2.467210808
100° 57' 55.194"	4° 22' 41.825"	534.2	1006.7	1833.2	1563.9	2.325295276
100° 57' 55.194"	4° 22' 52.175"	537.2	1010.1	1803.6	1554.6	2.112103618
100° 57' 55.194"	4° 23' 2.525"	540.1	989.7	1793.4	1550.7	2.173030449
100° 57' 55.194"	4° 23' 7.7"	533.2	914.6	1750.1	1553.24	2.066760594

	100° 57' 55.194"	4° 23' 12.875"	539.4	973.8	1771.3	1544.7	2.090471607
	100° 57' 55.194"	4° 23' 18.05"	535.1	965.6	1761.4	1532.7	2.133300297
	100° 57' 55.194"	4° 23' 23.225"	542.72	981.81	1824.83	1505.22	3.67500837
	100° 57' 49.382"	4° 22' 41.825"	541.43	983.75	1793.8	1554.7	2.176557425
	100° 57' 49.382"	4° 22' 47.0"	537	993.2	1798.13	1558.13	2.110083256
	100° 57' 49.382"	4° 22' 52.175"	541.8	987.54	1801.23	1552.47	2.262869327
	100° 57' 49.382"	4° 22' 57.35"	538.7	990.2	1799.86	1548.6	2.254794247
	100° 57' 49.382"	4° 23' 12.875"	540.4	982.53	1778	1541.32	2.152007788
	100° 57' 49.382"	4° 23' 18.05"	539.4	994.52	1795.5	1540.86	2.270151636
	100° 57' 43.57"	4° 22' 41.825"	543.41	990.67	1824	1554.2	2.520342612
	100° 57' 43.57"	4° 22' 47.0"	537.9	978.2	1801.59	1560.64	2.208678204
	100° 57' 43.57"	4° 22' 52.175"	540.2	998.3	1814.5	1554.8	2.308971774
	100° 57' 43.57"	4° 22' 57.35"	535.5	987.2	1820.62	1556.86	2.403426626
	100° 57' 43.57"	4° 23' 12.875"	538.81	984.46	1799.8	1553.91	2.230927113
	100° 57' 43.57"	4° 23' 18.05"	535.6	969.3	1804.49	1554.26	2.363874203
	100° 57' 37.758"	4° 22' 41.825"	538.6	950.06	1791.19	1565.76	2.211793797
	100° 57' 37.758"	4° 23' 2.525"	543.86	964.25	1799.6	1543.5	2.5588289
	100° 57' 37.758"	4° 23' 7.7"	532.5	923.8	1774	1552.3	2.307193396
	100° 57' 37.758"	4° 23' 12.875"	536	1012.5	1828.49	1566.18	2.224660348
	100° 57' 31.946"	4° 22' 47.0"	537.06	1003.89	1834.4	1551.4	2.539465811
	100° 57' 31.946"	4° 22' 52.175"	538.8	917.2	1760.9	1554.2	2.203843914